MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

INDIA.

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VOL. VII.

PUBLISHED BY ORDER OF HIS EXCELLENCY THE GOVERNOR GENERAL OF INDIA
IN COUNCIL,

UNDER THE DIRECTION OF

THOMAS OLDHAM, LL. D.,

Fellow of the Royal and Geological Societies of London; Member of the Royal Irish Academy; Hon. Mem. of the Leop-Carol. Academy of Natural Sciences; of the Isis, Dresden; of the Roy. Geol. Soc. of Cornwall: Corr. Mem. of Zool. Soc., Lond., &c., &c.

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CONTENTS.

MEMOIRS

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On the VINDHYAN SERIES, *as exhibited in the* NORTH-WESTERN *and* CENTRAL PROVINCES *of India, by* FRED. R. MALLET, F. G. S., *Geological Survey of India.*

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CHAPTER I.—AREA: PREVIOUS OBSERVERS.

The area to be described in the ensuing paper is one which had often attracted attention previously to its examination by the Survey. Covering, as the Vindhyan strata do in this single area, a surface not

greatly inferior to that of England, and no inconsiderable fraction of India, it would be strange had they escaped investigation. And although less varied in their geological relations than those of other districts of smaller extent, they are not wanting in many points of interest to lead one to their examination. Numerous, however, as the observers have been, their labours were all confined to limited portions, and the vastness of the area which the Vindhyans occupy rendered it impossible for one geologist to co-ordinate with certainty his results with those of others in distant localities. Even now large tracts of country exist in India concerning which our knowledge is so scanty as to prevent our deciding whether the rocks there belong to this formation or not. As, however, the survey of the Vindhyans has now been in progress for some years, and it must still be long before the examination is complete, it has been thought advisable no longer to delay the publication of the results hitherto obtained. It is in the area now finished that the formation is typically displayed. It is to a certain extent independent; and the description of its geology is not likely to be seriously affected by the working out of the remaining districts.

Preceding observers.

Before entering on this description, it may be useful to give a brief summary of what had been effected by our predecessors in the same field. Of these Captain Dangerfield * seems to have been the first, but only a small section of his memoir refers to the Vindhyan area. He found that the northern part of Malwa is chiefly occupied by sandstones and sandstone-slates, and that these rocks, after passing round at a short distance south of Jowra, also extend down its western boundary. The sandstones are generally very fine grained, some varieties affording very valuable building stone. At Jeerun he notes the occurrence of "numerous vegetable remains, or impressions of a species of fern, appearing

1823, Captain Dangerfield.

* Memoir of Central India by Sir John Malcolm, Appendix II.

to be in a carbonized state," between the slaty fracture of sandstone slate; and in other places limestone was found.

1825, Dr. Voysey.

Dr. Voysey,* in a paper 'On the building stones and Mosaic of Agra,' describes the sandstone of which that city is erected. He states, without, however, giving any reason, that it belongs to the old-red-sandstone formation of Werner, and believes that it will be found incumbent on granite, as he had invariably found it in the Peninsula of India and other parts of Hindostan. He conjectures that the Agra sandstone forms part of the great spread of rock, on the north-east boundary of which are found Futtipur-Sikri, Machkund, Dholpur, Gwalior, Kallinjer, Chunar, and Rotasgurh, a conjecture the correctness of which has been since clearly proved, although the sandstones of Gondwana to the south-west, which he also includes, have been found to be unconnected with the Vindhyan series.

1828, Captain Franklin.

The results of Captain Franklin's examination of a portion of Bundelkund and adjoining districts are embodied in his paper presented to the Asiatic Society of Bengal.† Starting from Mirzapur, he proceeded by the Tara and Kuttra ghâts to the Rewah plateau, describing the sections of sandstone observed at these passes and at the various waterfalls between them and the Tonse. He arrived at the conclusion that these rocks are to be identified with the *new-red-sandstone* formation, and considered it probable that the "*red* and *bluish green slaty marle* interstratified with *sandstone*" met with near the top of the Kuttra Pass represented the *red marle* of England. From Hatti (Hathi) to Patteriya Captain Franklin passed chiefly over limestone, which he concluded was 'lias,' and found "red marle" underlying it in some localities, as at Sohawel and Hutta. At Nagode (Nagound) this limestone is stated to contain "fragments of fossil wood, also fragments of stems of ferns, and one piece exhibited what I took for an impression

* Asiatic Researches, Vol. XV, p. 429.

† Asiatic Researches, Vol. XVIII, p. 23, and Geol. Trans., 2nd Series Vol. III, p. 191.

of the Gryphite shell, which is peculiar to this formation." At Patteriya the limestone "comes in contact with the *trap* rocks, and is thereby changed both in appearance and nature." From Patteriya to Ságar and thence southwards to Tendukaira trappean rocks were passed over, the lithological characters of which are described, and those of the earthy limestone, which in some places was found underneath and associated with the traps, and which Captain Franklin hints may possibly represent the oolitic formation of England. The remainder of the paper refers to a tract of country not included in this report, but before passing on, it may be well to point out how the survey operations have modified the above views. Although the absence of fossils has hitherto prevented an accurate correlation of the Vindhyans with any one of the European formations, enough is now known to assert with confidence that they are much older than the new-red-sandstone, and the idea of their being saliferous, which was one of Captain Franklin's strongest reasons for the above opinion, has also proved erroneous, as regards at least all the area included in his map and yet examined by the survey. The limestone also, which he regarded as *lias* and distinct from the Vindhyans, has been shown to form a sub-division of these rocks with which it is interstratified. With regard to details, such as the supposed alteration of the (Bundair) limestone at Patteriya and identification of the Kuttra shales with those at Sohawel, it is unnecessary to speak. No geologist simply traversing a perfectly new country could well avoid falling into some such errors, and Captain Franklin's paper added much to the scanty knowledge previously possessed respecting the geology of that part of India.

1829, Mr. Hardie.

Mr. Hardie* has described the sandstones and shales of Neemuch, in which no fossils were found, except one specimen, which appeared to be the impression of a portion of a cryptogamous plant. He agreed with Captain Dangerfield that these rocks

* Asiatic Researches, Vol. XVIII, Part II, p. 27.

ought to be classed with the new-red-sandstone, but remarked the absence of both rock-salt and gypsum which characterize the English formation. He believed that the Neemuch (Nímach) beds might perhaps hereafter be found a continuation of Franklin's sandstone formation, an opinion the correctness of which has been since verified. The limestones of the Neemuch country are stated to overlie the sandstones, &c., and their age is conjectured to be lias. Mr. Hardie describes the organic remains of these beds as numerous, and gives figures of three of them, which, however, he was unable to refer with certainty to any particular genus.

1830. The anonymous author* of a paper on the geology of the Bhartpur District divides the rocks of this region into those which immediately underlie the alluvial deposits (the Vindhyan sandstones) and strata probably of an anterior date to those which "here and there basset out, forming, especially in the northern portion, small detached hills and collines, which are generally topped by a village. To the west, again, this district is flanked by a belt of older rocks, which extends in a north-easterly direction from Biana, and which is interposed between the newer sandstone and the decidedly primitive formations of the Jépur and Ajmér territories." He considers the sandstones, now called Vindhyan, to be identical with the new-red-sandstone of England, and in an economic point of view divides them into three varieties, of which the last, a salmon-colored kind passing into greyish white, is the finest stone, as the red varieties are rather liable to decomposition. The remainder of the paper refers to the area lying to the north-west, the quartzite-sandstones of which belong to a pre-Vindhyan epoch.

1831, Rev. R. Everest. In most of the foregoing, as well as in some of the following papers, it will be seen that the Vindhyans are described as identical with the "*new-red-sandstone* of the English geologists." The Rev. R. Everest ably discussed this

* Gleanings of Science, Vol. II, p. 143.

question,* showing the inconclusiveness of the evidence adduced, which he sums up as follows: 1st, that the formation includes a number of beds of variegated marls and grits; 2ndly, that it is quarried for architectural purposes; 3rdly, that it is saliferous; 4thly, that it is horizontally stratified; 5thly, that it is unconformably stratified. In his reply he shows that variegated marls and grits occur in the *old* as well as in the *new* red-sandstone of England; that with regard to the second reason, the assertion will equally apply to most of the sandstone of the coal formation, as well as of the old-red-sandstone; that there is no direct evidence of the existence of salt in the Vindhyans,† and that the horizontal and unconformable stratification of the new-red-sandstone in England is a circumstance peculiar to that country, which need not, and does not always, obtain elsewhere. Mr. Everest further doubts Franklin's identification of the Nagode limestone with the lias, his reason being the absence of shells, which abound in the latter. He conjectures correctly that we ought to assign to the Vindhyans an earlier place than the new-red, though he is less fortunate in his reasons for this opinion. He regards all the coal-fields between the Sone and Hooghly as outliers of the Vindhyans, since "we have reason to believe that the Bundelkund formation contains coal," and he appears to assume that the Indian coal must necessarily be of carboniferous age. We know now that the Damuda coal-fields belong to an epoch quite distinct from, and more recent than, the Vindhyans, which latter contain *no* coal. Neither do they present "frequent passages into granite or gneiss," although altered locally into quartzite.

1832, Rev. W. D. Conybeare.

Mr. Conybeare, in his report on geology‡ to the British Association, gives, when referring to India, an abstract of the information then possessed regarding the Vindhyan rocks, which, amongst many accurate statements, contains several

* Gleanings of Science, Vol. III, p. 207.

† The name Vindhyan is used here and in other places to avoid circumlocution, although it was first applied to the series only in 1856 by Dr. Oldham.

‡ Second report of the British Association, p. 395.

that are erroneous. It is, however, unnecessary to specify these, as his authorities respecting Central India were chiefly those already mentioned.

1833, Rev. R. Everest.

In a paper by Mr. Everest* the rocks met with on the route from Mirzapur to Ságar are described, the observations being close and accurate, but from his being merely a route survey, little attempt could be made towards referring the different rocks to their relative stratigraphical positions.

1833, Captain S. Coulthard.

The trap formation of the Ságar District was described† by Captain Coulthard, who begins by pointing out its limits, and then discusses the physical character of the country, showing the different aspects which it presents, according as sandstone or trap prevails. The general elevation is described, of which the neighbourhood of Ságar seemed to form the culminating portion. Captain Coulthard then details the lithological character of the trap and the included minerals, and those of the limestones very commonly found associated with it. He inclined to the opinion that this limestone was the "neighbouring lias" (Bundair limestone), "half calcined and disguised by the trap." The sandstone is then reviewed, which from its lithological characters and horizontality, he concluded must be the lower division of the new-red-sandstone. Details are further given of the various routes by which he traversed the country, one of which crossed the ferruginous beds of Hirapur (Bijawurs), and a map is appended at the end of the paper, in which, as in Captain Franklin's, the limits of the trap and sandstone, as far as regards the Ságar country, are laid down with a considerable degree of accuracy.

1833, Capt. J. Franklin.

In the same volume is a paper by Captain Franklin on the diamond mines of Punna, in which the mode of mining for the gems and the various descriptions of diamond, &c., are described in detail.

* Journal Asiatic Society, Bengal, Vol. II, p. 475.

† Asiatic Researches, Vol. XVIII, Part. I, p. 47.

On account of statements made to Government by a Mr. Hyland, of his having discovered coal near Bijigurh Fort on the Sone, south-south-east of Chunar, Mr. Osborne, of the Opium Department, was despatched to investigate the matter, who reported* that the supposed coal was nothing but black shale and perfectly valueless. He examined the neighbourhood closely, and mentions the different rocks seen, amongst which no trace of coal was to be found.

1837, Mr. Osborne.

Dr. J. G. Malcolmson, writing 'On the age of the diamond sandstone and argillaceous limestone of Southern India,†' states his conviction that they belong in this respect to the "more ancient secondary or even transition rocks," and looks upon them as the same formation as the sandstones and limestones of Bundelkund and Malwa, dissenting from Captain Franklin's conclusion that the latter rocks represent respectively the new-red and the lias.

Dr. J. G. Malcolmson.

M. Jaquemont, on his journey from Calcutta to Delhi, passed over some of the ground which Franklin had previously explored. Leaving Mirzapur he ascended first the Tara and then the Kuttra ghát, the beds in which are minutely described.‡ He found the strata of the latter hill to overlie those of the former, and pointed out the absence of any primitive rocks at the foot of Kuttra ghát, as represented in Franklin's section. After travelling some distance from the edge of the second plateau on sandstone, limestone first made its appearance near Mowgunge, resting, apparently, on the sandstone, and containing argillaceous beds interstratified in the lower part. From this town to Rewah similar beds (limestone) were seen at intervals, but at Oomree, six miles west-south-west, sandstone (lower Bundair) again occupied the surface, which, however,

1841, M. Jaquemont.

* Journal Asiatic Society, Bengal, Vol. VII, p. 839.

† Geol. Trans. Lond., 2nd Series, Vol. V, p. 568.

‡ Voyages dans l'Inde pendant les années, 1828-32, Tome 1, p. 374.

M. Jaquemont regarded as a re-appearance of the Kuttra rock. South of Putrahut a third plateau was seen, the slopes of which exhibited shaly beds (Sirboo shales) in the lower part, while a lesser thickness of sandstone (upper Bundair) capped the whole. Captain Franklin's statement of having found petrified wood and impressions of ferns in the limestone at Nagode induced a similar search by M. Jaquemont, but without success. He does not quite seem to have recognised the Punna range of hills as the continuation of those at Kuttra, but speaks of it as forming a *third* very distinct plateau. After leaving Punna, the diamond mines of which are described in detail, M. Jaquemont proceeded by Bisramgunge ghât to the hill forts of Adjigurh and Kallinjer. At all these places syenitic rocks were seen on the slopes of the hill, covered at the top by a capping of sandstone (Kymore), and at Adjigurh, the author alludes to porphyritic bands intercalated in the lower portion of the latter. He believed that this sandstone represented the new-red-sandstone of English geologists, and that of Tara and Kuttra ghâts belonged to another formation.

1842, Dr. J. Adam.

Dr. J. Adam has described* the rocks met with on his route "from the Jumna to the Nerbudda by Banda, Lohargong, Bellary and Jubbulpur." He depicts the physical aspect of the Bundelkund crystalline hills and the manner in which he conceives them to have been formed by local elevation and subsequent modification by atmospheric agencies. The formations of this part of the country are divided by him into four, the order from below being granite, trap or basalt, sandstone and gravel. In the last, Dr. Adam says, the diamond mines are situated, and he gives an account of the method by which the gems are extracted. Information is also afforded about the soils, but the author falls into the mistake made by other observers of separating the (Bundair) limestone from the Vindhyans,

* Journal Asiatic Society, Bengal, Vol. XI, p. 392.

stating it to be of a formation posterior to the sandstone, and suggesting that it is the deposit of a great lake which once filled the valley between the Bundair and Punna hills. The paper closes with remarks on the metamorphic rocks of Jubbulpur.

1846, Lieutenant W. S. Sherwill.

In Lieutenant W. S. Sherwill's note on the geological features of Zillah Behar* are some allusions to the Vindhyan sandstones, but the paper refers more particularly to the crystalline area to the eastward.

1847, Lieutenant W. S. Sherwill.

The same author, in another paper, however, on Zillah Shahabad,† describes the physical features of the Kymore hills and table-land; then the sandstone of which these are mainly formed, and the "mountain limestone" (lower Vindhyan), which he correctly believes everywhere to underlie the former. The sacred caves of Gupta are referred to, and finally are enumerated the economic products of these hills, in which are included chalk, iron ore, indurated reddle, alum ore, martial pyrites, sulphate of iron, and potstone.

1852, Mr. D. H. Williams.

Amongst the posthumous papers of Mr. Williams was a report on his examination of the Kymore mountains, the chief object of which was to ascertain the correctness or otherwise of the general opinion that the strata of this range constituted a portion of the coal measures. Commencing in the neighbourhood of Akbarpur, Mr. Williams found beneath the sandstone which forms the mass of the hills there, a thin-bedded, bluish-grey, argillaceous limestone, resembling lithologically the lias limestone of Europe. Its thickness he estimated here at 700 feet, and no traces of organic remains were apparent. Not far from this a bed of coal was reported to have been discovered, which Mr. Williams found to be nothing more than a three foot band of black argillaceous shale. In marching up

* Journal Asiatic Society, Bengal, Vol. XV, p. 55.
† Journal Asiatic Society, Bengal, Vol. XVI, p. 279.

the course of the Sone silicious and altered beds appeared to the south of the Akbarpur limestone, and in one place a limestone was found which appeared to underlie the former, and hence to be one distinct from the Akbarpur rock. All these beds had a general northerly dip, although in places thrown into a series of trough-like undulations. In the neighbourhood of Bijighur the sandstone (Kymore) attained a thickness of 1,000 or 1,200 feet. Between this hill fort and Mirzapur nothing but sandstone was seen, and in returning from the latter place to the Sone valley a section was observed very similar to that previously described. To the east of Chunar limestone was again discerned at the base of the northern escarpment, and it seemed to Mr. Williams not improbable that it might be found at Chunar at a workable depth. Throughout the course of his investigations he saw nothing to justify his concluding that any coal existed in the Kymore mountains.

1853, Dr. Carter.

Dr. Carter, in his summary of the geology of India,* is rather unfortunate respecting his identifications of the rocks in Bundelkund. He places them in his 'Oolitic Series,' which he divides thus:—

TARA SANDSTONE.

KUTTRA SHALES { Shales. Limestone. Coal.

PUNNA SANDSTONE.

In this series he includes, along with the Bundelkund beds, strata described by Malcolmson in Southern India,† by Newbold near Kurnool, by Herbert in the Sub-Himalayas, and by Grant in Cutch, as well as the coal-bearing series of Bengal. From the fossils contained in the last and in the strata of Cutch, the age of the whole is provisionally taken to be oolitic. In his treatment of the subordinate groups he also comes to

* Jour. Bombay Asiatic Society, Vol. V, p. 179.

† Not improbably Vindhyan.

several erroneous conclusions, as, under the head 'Kuttra limestones' are included, besides others in distant parts of India, that of Bundelkund (Bundair), Rotasgurh (lower Vindhyan), and Jubbulpur (metamorphic), as well as the white crystalline marble of India generally. The Punna (Rewah) sandstone, that of the second plateau, is confused with that of Jaquemont's third range, the Bundair, and also with the Rotasgurh rock, which is that of the first, the Tara or Kymore. With the Punna sandstone are also classed strata in remote parts of India, some of which are known to belong to quite a different age, while the 'diamond conglomerate,' a subordinate bed of the Kuttra shales, is represented to overlie them and the Punna sandstone, and to be made up in part of their debris.

1856, Mr. A. Schlagintweit.

Mr. A. Schlagintweit has furnished a few observations* on these rocks which, with the coal bearing series of Bengal, and strata in different parts of Southern India, he includes in one formation, which he conjectures may be oolitic.

1856, Mr. Oldham.

The attention of the Geological Survey was first directed to Central India in 1854, and in 1856 Mr. Oldham gave to the Asiatic Society in Calcutta a summary† of the chief results obtained, which, as regards the sandstones of Bundelkund, showed that this great group was altogether of a different character and of a more ancient epoch than the beds associated with the coals of Bengal and of Central India, but that from the absence of organic remains there was as yet no evidence on which to base a reference of it to any established epoch of European geology; that the names hitherto assigned to this series and its sub-divisions being based on erroneous views of position, and therefore tending to erroneous conclusions, must be abandoned. Dr. Oldham, therefore, proposed the name *Vindhyan* for the whole

* Magnetic Survey of India, Reports vi & vii.

† Journal Asiatic Society, Bengal, Vol. XXV, p. 249.

formation, as being best seen in the scarps of the Vindhyan range, and divided it into subordinate groups, as follows, in descending order :—

1. Bundair ... ... Sandstones and shales.
2. Rewah ... ... Limestones, shales and sandstones.
3. Kymore ... ... Sandstones, and limestones and shales.

These groups and the names then given to them have been retained ever since, being found well marked nearly everywhere throughout the Vindhyan area yet examined, although it has been found necessary to introduce some changes in detail. More recent explorations have modified the views then held respecting the faulted nature of the Vindhyan southern boundary and the extension of the series to the eastward.

1860, Mr. H. B. Medlicott.

In 1860 Mr. H. B. Medlicott published his report* 'on the Vindhyan rocks and their associates in Bundelkund,' in which, retaining Dr. Oldham's groups, he proposed to classify *them* as follows :—

1. Bundair ... ... Sandstones and shales, with limestones.
2. Rewah ... ... Sandstone and shales.
3. Kymore ... ... Sandstones and grits, or shales.

Between the Vindhyans and the crystallines, and underlying the former, Mr. Medlicott found a series of limestones, shales and sandstones to which he gave the name *Semri*, and pointed out their strong lithological resemblance to a series of beds occupying a similar position in the Sone valley to which he had previously applied the name *sub-Kymore*, remarking at the same time, however, that closer examination might prove them to be a downward continuation of the Vindhyans themselves.

1860, Mr. J. G. Medlicott.

The same opinion was expressed by Mr. J. G. Medlicott, by whom, although not strictly belonging to his report, a short description† of the sub-Kymores and Vindhyans was given, which refers more especially to their development along the northern margin of the Sone and Nerbudda valleys.

* Mem. Geol. Survey, India, Vol. II. † Mem. Geol. Survey, India, Vol. II, p. 138.

CHAPTER II.—PHYSICAL GEOGRAPHY OF AREA.

Physical geography.

Viewed in a geographical equally as in a geological light, the area occupied by the Vindhyan rocks, especially in their eastern extension, is one well marked from the surrounding country, both by the greater general elevation of its plateau and the clearly cut escarpments by which it is almost everywhere bounded.

Vindhyan escarpment.

Almost the entire drainage of the Sone and Nerbudda is derived from the south, for the northern watershed of these rivers is the crest of the Vindhyan range, which with a mean elevation of 1,500 to 2,000 feet runs for some hundred miles parallel and close to their main streams. The southern declivities are precipitous and abrupt, forming that long line of escarpment to which the name 'Vindhyan' is more especially applied. To the north of the crest of the range stretch the table-lands and plains of Bundelkund and Boghelkund, which are sometimes found as elevated as that crest itself, but more commonly are reached by a glacis of moderate inclination. The northern faces are escarped very similarly to the southern, but the glacis is, on the whole, less prominent.

Northern escarpments.

Plateaus.

The district of which we are speaking is naturally divisible into three so-called table-lands, each of which has for its floor one of the three great sandstones of the formation, by the names of which, therefore,—Kymore, Rewah and Bundair,—the table-lands themselves may be conveniently distinguished. Commencing our survey at the eastward, the escarpments are everywhere bold and lofty, and the highlands west of Rotasghur have an elevation varying from about 1,000 to 1,400 feet. Their surface is uneven, hilly and rocky, and covered with thick forest jungle amongst whose glades are fed those herds of cattle which form the chief wealth of the scanty inhabitants. The drainage, which here as elsewhere is thrown north by the Vindhyan crest, falls by a series of waterfalls

Kymore plateau.

into the long winding gorges which convey it to the alluvial plains of the Ganges. But as we proceed westward, the general level sinks, and the hills become less prominent, until west of Shahgunj, the Tonse and its tributaries flow through plains of alluvium in which rock is seldom seen. The northern scarps at the same time of Mirzapur and Allahabad become much reduced in elevation, and the southern, instead of forming merely the edge of a plateau, becomes a ridge with a slope, although less steep still almost as great, on the north side as on the south. The Sone valley at Burdhee and the Kymore country to the north are of nearly equal elevation. Westward of Allahabad the Kymore plateau is reduced to a narrow strip of country between two escarpments, of which the northern, or Kymore, acquires in Bundelkund the elevation which it had lost in the Allahabad region. Thus it will be seen that the most elevated and the wildest part of the Kymore plateau is its eastern extremity, a fact which is also true of the Rewah and Bundair plateaux, the difference, however, being less marked in the Rewah than in either of the others.

Rewah plateau.

The general level of the Rewah table-land is tolerably uniform. The country is rocky and barren where the sandstone occupies the surface, but further from the edge, where the lower Bundairs appear, it becomes fertile and thickly inhabited. Much of this ground indeed is covered by alluvium. The southern boundary is the Kymore ridge, which slopes down to the north so much that south of Rewah the surface is only 100 feet higher than the Sone valley. West of Rewah the range becomes double, the intermediate valley being, in fact, the continuation of the Kymore plateau. The eastern and northern edges of the Rewah plateau are marked by another fine escarpment, over whose edge the drainage falls in a series of waterfalls of great beauty, varying in depth from 200 to 400 feet. In Rewah the southerly inclination from the edge of this escarpment is very slight, but it increases as

we proceed west, so that past Nagode we find ourselves in a broad valley bounded on one hand by the Bundair scarp, and on the other by the slope of the Punna ridge, until beyond Dumoh we arrive at the trappean hills of Central India.

Bundair plateau.

The part of the Bundair plateau east of the river Kane is the most elevated, being separated from the Rewah by a line of escarpment 500 to 800 feet high. The usual character of the country is that of low rolling jungle-covered hills; the streams which flow between them being bordered by a narrow strip of alluvium, on which the villages are situate, and where only there is any attempt at cultivation. The tract west of the Kane maintains very much the same character of rock and jungle, but it is on the whole lower. Much of it, indeed, is but slightly higher than the Rewah plateau to the north, for although the escarpment presents a northern face some hundred feet high, the surface slopes rapidly from the edge in a southerly direction. In general contour, however, the Bundair tract is more irregular than either of the others, some parts, like that west of Belhari, forming small isolated table-lands by themselves. Between Saenugurh and Rypora the usual jungles are replaced in part by grass-covered rolling plains.

Sone valley.

The Sone valley south of the Kymore escarpment is occupied by numerous ranges of hills, which never exceed a few hundred feet in height, and preserve a general parallelism to each other and to the Kymores for long distances. This configuration is owing to the diversity in the strata of the lower Vindhyans and older formations, and the disturbances by which they have been thrown up at various angles while preserving a uniform strike. As usual under these conditions, the softer beds have been cut out into long narrow valleys between the ribs and hills which mark the harder beds. These features are better developed amongst the schistose rocks than amongst the lower Vindhyans from greater disturbance and contrasts of

material in the former. The hilly character of the Sone valley is continued across the watershed into the basin of the Nerbudda as far as Kuttungee or somewhat further, beyond which the alluvial plains of the Nerbudda stretch up to the base of the Vindhyan escarpment.

Gangetic area and crystalline area of Bundelkund.

The Vindhyan area is bounded on the north by the Gangetic plains from Sasseram as far west as Banda, but the interior of the great curve, in which the boundary sweeps round from Allahabad to Agra, is partly occupied by gneissose rocks, which lend a new aspect to the country. The surface over a wide margin north of the boundary is slightly elevated above the alluvial plains, and the crystallines are everywhere seen rising here and there into hills, which, by their rounded form and want of regularity, strongly contrast with the serrated precipitous ridges which trend across the country for miles, marking the position of great quartz veins which intersect the gneiss. The direction of these is generally north-north-east or thereabout, and their elevation seldom exceeds 400 or 500 feet. Between the truly crystalline area and the alluvial plains there is no very definite line of demarkation, and out of the plains rise hundreds of gneissose hills, isolated or in groups.

Gwalior country.

The trappean area of Malwa approaches, west of Goonah, so close to that of the crystallines that the Bundelkund spread of Vindhyans is connected with that of Gwalior only by a narrow neck between Sâgar and Sipri. Here the Kymore and Rewah escarpments, brought close together by the extinction of the lower Rewah group, face to the eastward, and the surface slopes gently to the west until the sandstones disappear beneath the trap. In the absence of shaly beds of importance, the denudation has been less guided than in the eastern districts, and hence the different escarpments are not so clearly defined. But as we proceed north-wards

the shales re-appear, and each alternation of the strata is defined by a separate escarpment. In the neighbourhood of Sipri are four such, all facing eastwards, while from the edge of each the country slopes gently to the west. Towards Gwalior they trend somewhat east of north, until lost beneath the alluvium. Along the northern bank of the Chumbul, west of Dholpur, a fifth escarpment runs nearly parallel to the ridge which passes by Futtipur-Sikri and Hindoun. Northward and eastward stretch the alluvium plains, except near Gwalior, where the formation to which the name of this place has been given manifests itself in a series of east and west escarpments, whose form is very much the same as that of the Vindhyans.

Trappean area.

The trappean area is one which presents much diversity in aspect. Plains, more or less level as a whole, in some parts are covered with broad spreads of 'cotton soil,' where wheat is grown in immense quantities. Elsewhere the ground is broken and irregular, and the trappean rocks, without a covering of soil, prevent any but the scantiest vegetation. Innumerable hills, disposed singly, or in groups, and ranges, and plateaux of limited extent, diversify the prospect, some of them covered with jungle, others stony and barren. The form of the trap hills distinguishes them at once from inlying hills of sandstone, and the vegetation of each is also sufficiently distinct; one of the most characteristic differences being the abundant supply of teak saplings on the trappean hills, which are quite uncommon on the sandstone.

Escarpments.

Without exception the most prominent features of the Vindhyan area are the numerous escarpments, which stamp it with a geographic character peculiarly its own. Their form depends on the conditions, the nature, and the inclination, of the strata composing them. The commonest form where the lower portion of

the scarp is shale and the upper sandstone exhibits an under-cliff of about 30° inclination, with a vertical precipice above; the relative magnitude of cliff and under-cliff depending chiefly on the ratio of shale to sandstone. When the latter is absent, the scarp preserves a uniform slope from top to bottom, while the boldest precipices are found where the scarp is entirely sandstone, the under-cliff then being made up of a talus from above. Where, as sometimes occurs, there are two bands of sandstone separated by shale, the escarpment is usually divided into two distinct terraces. The other condition, the inclination of the strata, also greatly affects the form. The beds may be either horizontal, dip from the face of the escarpment, or dip towards it, and, as a general rule, the cliff of the escarpment is perpendicular to the stratification, and the surface in from the edge or glacis, parallel to it. Hence, in the first case, the cliff is found to be vertical and the country above the escarpment horizontal. In the second, the cliff is not quite so steep, and the country slopes from the edge with an inclination equal to that of the bedding, whilst in the third case, the escarpment degenerates into an easy slope without cliff of any kind. The combination of the above elements produces every variety of form met with, and a geologist acquainted with the country could accurately picture to himself the outline of any escarpment, without seeing it, if he were told of what rocks it was made and how they were disposed.

Outliers.

Along some lines of scarp outlying hills are very frequent, whose elevation is equal to, or greater than, that of the main scarp, according as the stratification is perfectly horizontal or dips gently *from* the outlier. On such eminences, either wholly or semi-detached, have been constructed those hill forts which once played such a prominent part in Indian history. Amongst many others may be mentioned Rotasgurh, Chunar, Kallinjer and Gwalior.

The gorges which receive the rivers after their descent from the plateaux should also be mentioned in a description of the physical aspect of the country. After a clear drop of two to six hundred feet, the water plashes into a deep tarn scooped out by its continual falling, on leaving which it runs through a channel often several miles in length, and obstructed, throughout its course, with huge masses of rock fallen from above. From each side of the stream rise the under-cliffs of the escarpment covered with tangled jungle and debris, and crowned by vertical precipices, which cut off all access to the plateau above, save by one or two narrow paths known only to the wood-cutters and charcoal-burners, by whom only the gorge is ever visited.

Gorges.

The general elevation of the Vindhyan area differs considerably in different parts. Thus the eastern portion of the Kymore plateau averages perhaps 1,500 feet, but sinks at Ghorawul to 900, and at Lalgunj to 500.* The Rewah country is more uniform, the general level being 1,000 to 1,200, and a considerable portion of the Bundair is not much higher. Other parts, however, are little short of 2,000 feet. Throughout the Vindhyan area few points exceed the last-mentioned figures, which express the mean elevation of the highest hills, like Bijigurh (2,017), Amua, (2,176), and Myhere, (2,039); the culminating point is Kalumur, a trappean hill rising from the Bundair table-land 2,544 feet above the sea.

Elevation of the country.

The mean level of the Gwalior country does not seem to exceed 1,200 feet; it is about 1,500 at Sipri, but reduced by a general northerly slope to 1,000 at the Chumbul. The trappean area is considerably more elevated; the highest peaks there rivalling in altitude those of the Vindhyan range of hills. With regard to the river valleys in the south, the

* These figures are from various sources, most of which are quoted in Mr. Schlagintweit's Hypsometry of India.

altitude of Kuttungee, a town near the watershed, is 1,350 feet, but the Nerbudda at Hoshungabad is reduced to 1,050, and the Sone at Akbarpur to 400. Proceeding hence along the northern limits of the formation, we find the Gangetic plains at Allahabad only 300 feet above the sea, and the crystalline area of Bundelkund considerably less than 1,000.

Drainage.

Except an insignificant surface drained by the Nerbudda, the whole area occupied by the Vindhyan rocks belongs to the basin of the Ganges. The Sone flows through the country of the lower division of the series, while the Karumnassa, the Tonse, and the Kane carry off the superfluous waters from the upper Vindhyan area east of Saugor. North and north-west of this town, the Dessaun, the Betwa and the Sind flow across the sandstones on their way from the trappean area to the plains of the Ganges, while the Gwalior country and all the western extension of the Vindhyans is drained by the Chumbul and its various affluents.

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Chapter III.—Formations overlying and underlying the Vindhyan rocks.

Before commencing the description of the Vindhyans themselves, we shall enumerate the different formations which under-and over-lie them, or which are found in their vicinity, but it will be unnecessary to attempt any detailed description of these. Some have been already described in these Memoirs, and reports on others will make their appearance before long, while the geology of some portions is as yet too little known to justify any detailed account of them.

Older formations.

Gneissose rocks make their appearance in three distinct and widely separated regions. The largest of these is in Bundelkund, where they occupy the great 'bay' included in the curve of the Kymore scarp between Allahabad and Gwalior, underlying unconformably all the other formations of that country. They also occupy a large tract in the Sone valley, intervening between the slate or schistose series and the coal-bearing rocks to the south, and are again found in the Nerbudda valley at the eastern end of the Dhar forest. Gneiss also underlies the Vindhyans to the west of Neemuch beyond the limits of our map; there is as yet no reason for disbelieving that these separate spreads of gneiss belong to the same formation. Descriptions of these rocks in Bundelkund may be found in these Memoirs, Vol. II, p. 49, by Mr. H. B. Medlicott, and in the Records, Vol. I, p. 69. The Nerbudda gneiss has been reported on by Mr. J. G. Medlicott, Vol. II, p. 120.

Between the gneiss and the lower Vindhyans in the Sone valley, there is a very large development of shales and schists with other subordinate varieties of rock, constituting a series to which no definite name has as yet been attached. It seems not unlikely that the further examination of these rocks may show that they include two distinct series,

the upper resting unconformably on the lower, and being probably equivalent to the Gwaliors or Bijawurs of Bundelkund. The lower Vindhyans rest totally unconformably on the schists, which had been upturned vertically, and greatly denuded before the former were laid down, as will be seen further on when describing the Vindhyans themselves. The same schistose series is also largely developed on the south side of the Nerbudda valley, and has been there described by Mr. J. G. Medlicott.*

The Bijawur series, consisting chiefly of limestones, hornstones, quartzites and contemporaneous trap, has been reported on in Bundelkund by Mr. H. B. Medlicott;† it will be unnecessary, therefore, to allude to these further here, except to mention that the patches of limestone north-east of Heerapur conjectured to belong to the lower Vindhyans, and mapped as such have been found on more detailed examination to be referable to the Bijawur series, with which, therefore, they are included in the accompanying map. The trap also of the Bijawur area is, at least in part, contemporaneous.

We find the same formation again in the Dhar forest, resting there, as in Bundelkund, unconformably on the gneiss, and underlying the Vindhyans. As remarked also above, it seems probable that further investigation will show that the 'slate series' of the Sone valley includes, amongst its contorted strata, beds which belong to a different and newer series, representing either the Gwalior or the Bijawur.

The Gwalior group is made up of silicious and ferruginous beds, limestones, quartzites and contemporaneous traps, and underlies the Vindhyans with complete unconformity; but the relations of these rocks to the Bijawurs, to which they bear some general resemblance, are as yet unsettled. Both occupy a position between the gneiss and Vindhyans, but they are widely separated geographically.

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* Vol. II, p. 130.

† Vol II, p. 35.

Quartzite series.

Along the north-western boundary, in the neighbourhood of the Bunas river, Mr. Hacket last season (1868) observed a vast development of white quartzite sandstones, which are unconformably overlaid by the Kymores on the north-west and are brought in contact with the Bundairs on the south-east by means of a great fault. Similar beds also occur in the hills west of Biana just beyond the limits of the map, being there, as well as at the Bunas, interstratified with contemporaneous trap and more or less shale. The occurrence in these strata of jasper pebbles from the Gwaliors, and the unconformable superposition of the Kymores, almost proves them to be intermediate in age between these two formations, and they have provisionally been called the 'quartzite series.'

Newer formations.

The great Deccan trap covers a very large area of the Vindhyan rocks south of the Nerbudda to the east of Neemuch and Burwai, stretching eastward nearly as far as Dumoh. It rests unconformably on the denuded and sometimes disturbed strata, and has itself suffered extensively from denudation, leaving a very irregular boundary with frequent outliers and inliers. The most easterly point which it attains is Kalumur hill above Kuttungee, which, rising to an elevation of 2,544 feet, forms the culminating point of the Vindhyan area. The boundary is sometimes, as east of Saugor, marked by a clear trappean escarpment, but in other parts it is indicated by no physical feature. The Vindhyans have in places been somewhat altered immediately beneath the trap, but not to any very great extent. To the east and south-east of Saugor the infra-trappean or Lameta limestone is largely developed, attaining a thickness of over 100 feet in places, but it varies greatly in this respect, sometimes being entirely absent, the trap then resting directly on the Vindhyans. The rolled pebbles which often make up a considerable portion of its bulk have been derived from the Vindhyan sandstones. These rocks have been discussed by Mr. H. B. Medlicott,* by Mr. J. G. Medlicott, † and by Mr. W. T. Blanford. ‡

* Memoirs, Vol. II, p. 76.

† Memoirs, Vol. II, pp. 196 to 217.

‡ Memoirs, Vol. VI, p. 137.

Somewhat beyond the limits of the map, about Seronj and Goonah, and thence northwards towards Sipri, the trap is covered by immense spreads of rock-laterite, which attains a considerable thickness, and rests on the lower series with a perfectly sharp junction. Small outliers are found for a long distance to the eastwards, as on the top of the Bundair escarpment above Doorcha, on Sirboo hill, and along the Punnah range of hills as far as Simereeah, north of Rewah. It is frequently underlaid by some yards of white and lilac clay, from which one or two doubtful mammalian bones have been obtained, and which sometimes includes segregations of brown hœmatite, which is worked as iron ore.*

The Gangetic alluvial plains run up to the base of the Kymore escarpment from the debouchure of the Sone at Rotasgurh to beyond Kallinjer fort, and again from the limit of the Vindhyans from Gwalior northwards to Futtipur-Sikri, and thence for a long distance to the south-west, until schistose rocks come in between. The Nerbudda alluvium is also found in contact in the Jubbulpur and Hoshungabad districts.

In addition to the above, we may mention the blown sand-hills which occur to the west of Agra, and increase in size and number as we proceed westwards. In the hot weather the westerly winds, after blowing across the great desert, come charged with sand. The heavier particles are driven along the surface of the ground and become rolled

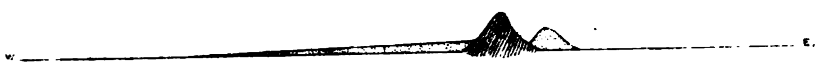

Fig 1. Mode in which sand is heaped up against any obstacle.

or heaped up (Fig. 1) on the windward side of any obstructing hill. When, as is often the case, the sand is driven into a gorge, or valley narrowing to-

* Vide Vol. II, p. 78.

wards the upper end, it accumulates to a great depth, and is subsequently cut into deep channels by the periodic rains. To the leeward of the hills, an eddy is formed in the air, by which the finer particles suspended in it are deposited, and in course of time give rise to a hill, sometimes almost rivalling in size the one to which it owes its existence.

The Vindhyans of Bundelkund having been reported on by Mr. H. B. Medlicott in 1860, their further examination in the upper Sone valley was taken up in 1860-61 by Mr. J. G. Medlicott and myself. During the next season Mr. C. A. Hacket's services were similarly directed further east, since which time he and myself have been principally engaged on these rocks; Mr. Hacket in Bundelkund and the northern portion of the map, the whole of which to the north of Sipri is exclusively due to him. Mr. Medlicott has also spent a considerable time in their examination in the Sone valley, and their westerly extension towards Neemuch. During the last two seasons, Mr. W. L. Willson has carried on the investigation in the Saugor and Jubbulpore districts, while the Dhar forest is principally due to Mr. W. T. Blanford. My own work has been chiefly on the upper Vindhyan area, between Sasseram and Dumoh, and in the Nerbudda valley. The present report is intended, therefore, to combine the work and results of all these observers.

Chapter IV.—Sub-divisions of Vindhyan Series.

These recent investigations have proved the correctness of the surmise that the 'Sub-Kymore' series of the Sone valley and the 'Semri' series of Bundelkund were the same; at the same time establishing their close connexion with the formation hitherto known as the Vindhyan. This connexion, although close, is not sufficiently so to warrant our including both in one series. Hence the latter are now called *Upper Vindhyan*, the Semris and Sub-Kymores being distinguished as *Lower Vindhyan*. In the middle of the Rewah, and also of the Bundair shales, a considerable thickness of sandstone has been found dividing them into two distinct bands. Hence the names "Rewah shales" and "Bundair shales" become inapplicable, since the former include two shales and a sandstone, and the latter, two shales, a sandstone, and a limestone. Each of the three upper Vindhyan groups has, therefore, been divided into an upper and lower sub-group; but as the lower Rewah and Bundair each includes two shales, it has been found necessary to give them local names to avoid the confusion which would arise from speaking of, say, 'upper Bundair shales' as a part of the 'lower Bundair' sub-group.

The classification of the Vindhyan formation in Northern India, as it stands at present, is as follows:—

Upper Vindhyan.

Bundair ...	Upper Bundair ...	Upper Bundair sandstone.
	Lower Bundair ...	Sirboo shales. Lower Bundair sandstone. Bundair limestone. Gunoorgurh shales.
Rewah ...	Upper Rewah ...	Upper Rewah sandstone.
	Lower Rewah ...	Jheeree shales. Lower Rewah sandstone. Punna shales.
Kymore ...	Upper Kymore ...	Upper Kymore sandstone. Kymore conglomerate.
	Lower Kymore ...	Bijigurh shales. Lower Kymore sandstone.

Lower Vindhyan.

11. Limestone.
10. Shales.
9. Limestone.
8. Shales, sandstone.
7. Limestone.
6. Shaly sandstone.
5. Porcellanic shales.
4. Trappoid beds.
3. Porcellanic shales.
2. Limestone.
1. Conglomeritic and calcareous sandstone.

The Sirboo shales derive their name from an outlying hill of the Bundair plateau north of Amarpatan; the Gunoorgurh from a hill fort north-west of Hoshungabad, in which localities the respective sub-divisions are finely exposed. The Jheeree are called after a town in the Gwalior country, situated near the foot of the escarpment which marks the out-crop of these beds; the Punna from the well-known town in Bundelkund; while the hill fort of Bijigurh gives its name to the shales of the Kymore group, which are well seen on the slopes of the hill where this stronghold is built.

Chapter V.—The Lower Vindhyans.

The lower Vindhyan series occupies two distinct tracts of country; one in Bundelkund and another in the Sone valley. The first has been already described in the second volume of these Memoirs, and it is with the Sone region that we are particularly concerned in the present report.

There the series under discussion occupies a narrow slip of country along both banks of the river, between the Kymore escarpment on one side, beneath the sandstone of which its strata dip, and the slate series and gneissose rocks on the other, on which they rest with a strongly marked unconformity, and out of whose debris their lower beds have been partially formed. The series, although frequently much contorted and disturbed, has throughout a general northerly dip from the older towards the newer rocks, and, as a general rule, the inclination decreases in amount from south to north; the upper members of the series are less inclined than the lower. The disappearance of the lower Vindhyans near Bilheri is due to faulting, not to extinction; but west of this they are only seen once again in some small outliers near Kuttungee. Along the upper part of the Nerbudda valley a great fault brings the Rewah group in contact with the metamorphic series, thus sinking the lower Vindhyans out of sight. We cannot, therefore, determine the exact point at which they finally die out, but at the first natural junction seen in the Dhar forest, no trace of the series remains. The probability is, that they do not exist very far west of Kuttungee.

Along the northern face of the escarpment they are seen occasionally between Sasseram and Chynepur, but disappear completely west of this throughout an interval of more than 200 miles, in which no trace of them is found. After their re-appearance near Tirhowan, they are seen almost uninterruptedly until their final extinction to the west. There can be little doubt of their being continuous across this gap, and that their non-appearance is merely due to their never rising above the Gangetic alluvium.

In Bundelkund they thin out westwards and become extinct north of Saugor. Their western overlap is thus established on both north and south; their extreme length from Rotasgurh to where last seen in Bundelkund being 350 miles.

For more than one reason the lower Vindhyans do not admit of the same accuracy of classification as the upper. The sub-divisions which exist in any one section are not all to be found in another at a considerable distance; the difference arising partly from a tendency they have in some cases to die out, and in others to lateral change in lithological character. The much greater disturbance which the lower series has undergone, the absence of such clearly defined physical features, corresponding to the geological lines, as are met with amongst the upper, and the want of good maps on which to record one's observations, all combine to render a detailed classification of the lower Vindhyans applicable to their whole extent, a work requiring more time than could justly be given to it by the survey. The division of the series given at page 28 is that which is found to obtain in the eastern area. Some members can be traced almost continuously all along, but the identification of others in the west with those in the east is to a certain extent conjectural. The relative importance of the different members is very different. Some are constant and preserve a tolerably uniform thickness for long distances, while others are only to be found in certain localities, even there sometimes occupying a subordinate position. The lowest beds are less constant than those higher up, a reason for which suggests itself in the original conditions of deposition. The floor on which the series was first laid down was a most uneven one, formed by the hills and valleys which marked the alternating hard and soft highly inclined beds of the older slate series. After the first Vindhyan strata had filled up such depressions, the more even floor then produced naturally led to greater evenness of stratification in the succeeding beds.

1. Conglomeritic sandstone.

Towards the east, whenever the conglomerate occurs, it is found resting with total unconformity on the vertical or nearly vertical beds of the slate series. Fine examples of this present themselves south-east of Khone Khas, where the conglomeritic sandstone perhaps attains its greatest development, and in the neighbourhood of Agoree Khas. For instance, on the slope of the hill west-30°-north of Keonda the vertical reddish slates strike west-10°-south. Resting immediately on these is 15 or 20 feet of coarse thick-bedded conglomerate, the slightly rolled pebbles (up to 6 and 8 inches diameter) being chiefly from the red jasper of the older rocks. Over this 3 or 4 feet of thin-bedded yellow and reddish sandstone is exposed, the lowest part containing small pebbles: dip east-10°-south, at 40°. Koodyla hill, of slates in a similar position, is capped in places by remnants of conglomeritic sandstone, a very thick-bedded and massive rock, in appearance sometimes not unlike the Kymore, but full of rolled pebbles of white quartz, red jasper and a few of green slate. The hill west of Bijowra is capped by about 150 feet of very coarse sandstone, with pebbles and grains of white quartz and a few of red jasper. It is coarser in the lower part than above, but none of it can be called conglomerate. Dip eastwardly at 10°: that of the slates 70° to south-15°-east. On the bank of the Sone at Agoree fort the red jasper of the lower series dips south at 60,° on which rest a few feet of conglomerates formed of pieces of the former with calcareous and arenaceous cement. Above this is 15 or 20 feet of thick-bedded, impure, light grey limestone, covered by 8 or 10 feet of very massive sandstone.

The above examples show the great capriciousness of the bottom conglomerate in both lithology and thickness. Near the Kunhur river it is not seen at all, although, from the nature of the ground, this cannot be taken as clear proof of its absence. In the neighbourhood of Khone Khas it is only the bottom part of this sub-division which is conglomeritic

for a thickness of about 80 feet. Above it is represented by a fine sandstone, in which are several bands of silicious limestone, occurring in 2 and 3 feet beds, sometimes intercalated with calcareous sandstone. The thickness of limestone where greatest is some 40 or 50 feet. In places some beds of it seem to have altered to a chalk-like appearance. Above the limestone the rocks become more shaly, with quartz and considerable quantities of iron, which supplies ore to a few native furnaces. These ferruginous beds, although of trifling thickness, are very constant, at least towards the east. Above them the limestone No. 2 comes in.

In some of the narrow ridge-like outliers scattered over the slate area south of the main spread, and which can generally be recognized at a distance by their peculiar configuration, the bottom conglomeritic sandstone attains a greater thickness than elsewhere, a fact probably connected with the original area of deposition. In the outliers, however, which occur in the alluvium south-east of Rotasgurh, the conglomerate is entirely absent, as well as the next two members of the series, and beds apparently representing the trappoid band, No. 4, rest directly on the crystalline rocks. There is a group of hillocks 10 miles north of Sasseram, which have all the form of granitic ones, but examination proves them to consist of a very coarse quartzose and felspathic sandstone, containing abundant rounded pebbles of a red felspathic rock and quartz. From their isolation in the alluvium their relations are uncertain; they might be Kymore, but the likelihood seems to be that they represent the bottom rock of the lower Vindhyans.

Between Agoree Khas and Burdhee the junction between the latter and the older rocks is obscured by alluvium, and the bottom conglomerate is not seen, although it probably exists along some part of this interval. From Burdhee westwards to near Kubra hill the low ridge of thin-bedded shaly sandstone, with occasionally a thicker bed of coarse

Fig. 2. Section across the lower Vindhyans, east of Khone Khas. A, gneiss: B, slate series: D, Kymore. The numbers refer to the sub-divisions of the lower Vindhyans (see page 28).

rock, which runs along the boundary, may contain some true representative of the conglomeritic sandstone, which is developed in the outliers to the south. To the north-east of Kubra hill it is certainly absent, shaly beds, which pass above into porcellanic ones, being seen to rest directly on the metamorphics. A few miles west of this eminence, however, it comes in again, and is thence seen continuously for more than 40 miles. At Murye, south-east of Ramnuggur, the boundary becomes of a very obscure nature. The conglomeritic rock, which deserves the name of quartzite rather than sandstone, attains a thickness of several hundred feet in the hills, yet for about two miles west of Murye not a trace of it is to be found along the boundary. A fault at once suggests itself; yet taking the normally uncertain development of this rock into account, it seems more simple to explain this and some other parallel cases by local peculiarities of deposition. The conglomeritic beds are also absent where the boundary crosses the Sone near Jhaal, but are found well developed to the west of this village.

2. Limestone.

The limestone No. 2 attains its greatest development in thickness and superficies east of the Rehund, where it forms a very important member of the series. To the east of Khone Khas (see fig. 2), it occurs in beds 3 or 4 feet thick, of a bluish color, the bottom 30 or 40 feet being very hard and silicious, scarcely effervescing with acids. The

middle is pure, but the upper part again is largely mixed with silica; indeed the boundary between this rock and the silicious ones above is not well marked, the passage between the two being very gradual. The thickness of limestone south-east of Khone Khas is perhaps 300 feet, but this is considerably increased between the Kunhur and Rehund. At Kujrahut the thickness of highly inclined strata is so great as to render it likely that they are repeated by doubling up.

West of the Rehund this limestone no longer forms a constant member of the series. Frequently it is entirely absent, while in some sections great, but very local, accumulations are found. Such are well seen on the pass south of Berouli, and better still forming bare rugged little hills south of Bergurah. It is along here, however, that the most conflicting cases occur of confusion with the limestone of the slate series. In several excellent river sections there is found close to the north limit of the slates a limestone unmistakably interstratified with the older rocks, and the question is, whether all the limestone seen here may not be this rock, the two being often undistinguishable in ordinary ground sections. The older rocks, however, universally exhibit a state of extreme compression and flexure, whereas the limestone of the hillocks near Bergurah only shows a moderate and steady disturbance; there is, moreover, a far greater thickness of it than has ever been observed in a clear section of the older limestone. Whatever series this limestone belongs to, its sudden appearance and disappearance is most difficult to account for; in fact it seems impossible on any other supposition than that of original limitation, unless indeed by the most arbitrary and unsupported use of faulting. Within half a mile east of the extensive spread of limestone this rock vanishes from the section. We find thin sandstones, with fine-grained and sub-porcellanic shales well to the *south* of (*i. e.*, inside) the run of the massive limestone; they exhibit considerable contortion, and the lowest rock seen is of an unusual type, a bright

red ochreous clay. In the Coorani stream this same rock is the first to show within 30 yards of the slates.

At Murye south-east of Ramnuggur, and again about the Sone, a limestone is met with which most probably should be referred in position to that we are now discussing, though here again there is some uncertainty whether it may not rather belong to the older series. Such uncertainty, however, can hardly be said to exist regarding the limestone at Koteesar on the Mahanuddy. This rock occurs in enormously massive beds, yet its whole superficial extent is only a few square miles. The occurrence, a short way up stream, of *porcellanic* beds, to all appearance overlying the limestone, strongly corroborates the opinion that the latter should be classed with the limestone of the Rehund.

There is much to suggest that, in many places, this rock is not subsequent, but equivalent to, and replaces the bottom conglomeritic sandstone; and it has been frequently observed that when one rock is thickest, the other is thinnest. Near Agoree they seem to pass into each other laterally. It would seem as if the present surface of the schist area approximately corresponds to the surface on which the bottom Vindhyan beds were deposited; that then, as now, it was relatively a more elevated area, and that upon it irregular accumulations of sand and conglomerate were laid down; while synchronously, upon and around this area, perhaps in deeper or more sheltered spots, the massive limestone was formed. The much greater thickness of the sandstone found in the outliers to the south, than in the band out-cropping at a lower level along the edge of the main area, suggests the complete and general absence of this band beneath that area.

3, 4, 5. Porcellanic and trappoid beds.

In the Khone Khas region the limestone No. 2 passes above into the rock to which the term 'porcellanic' has been applied. The latter occurs in beds from 2 to 3 feet thick, of a greyish color, and breaking with a splintery fracture.

Its character is very constant whenever met with. This and the two succeeding sub-divisions together form the greater part of the whole series south of the Sone in this region, occurring in a continuous line of hills close to that river, in the eastern part of which the dip is very regular, 10°-20° north; but to the west the strata are much more disturbed. Perhaps 200 to 300 feet may be taken as their thickness. Between Nos. 3 and 5 there is a band of most remarkable rock, the exact character of which remains yet to be determined. Its mineral constituents in the Khone Khas neighbourhood are hornblende, felspar and a small proportion of quartz, and the rock bears a strong resemblance to trap. Its thickness, where greatest at Hoorkahoorkee, may be 150 feet, but it becomes much thinner towards the west. The beds into which it is divided average 2 feet, and bands of the porcellanic rock of 5 or 10 feet are sometimes interstratified. The fact that porcellanic beds, identical in appearance with those of the Sone valley, are associated in the Gwalior series with undoubted contemporaneous traps, tends to support the conclusion that the beds in question are also of igneous origin. In the lower Vindhyan outliers south-east of Rotasgurh, however, the inferior conglomerate, &c., are absent, and we find at the base of the series a rock to all appearance the equivalent of that in question. It is here less trappoid and granitoid in aspect. It rests directly on granitoid gneiss, and its examination strongly leads one to believe in its being a sedimentary rock made up of the debris of the latter. The porcellanic strata which cover the trappoid band and which are generally the first rock met with south of the Sone from Hoorkahoorkee to the Rehund are somewhat different in composition and structure from those beneath. They are less purely silicious, and the term 'porcellanic' is more truly applicable to them. The beds, which are thin and divided into angular pieces by sharp joints, exhibit alternate white and grey, or black, or sometimes reddish, laminæ varying from a mere line to an inch or more in thickness, which give them a very

characteristic ribboned aspect. Such is their appearance at the base, but above they interstratify with bands of ordinary shale and sandstone, which increase in amount until they imperceptibly pass into another subdivision. No. 5 is much disturbed and contorted in this region, dipping in both directions, but the general inclination is northerly.

From the total extinction of the Keinjua range of hills near Burdhee, the middle bands of the series are greatly concealed between this village and Agoree. It is the most contracted portion of the lower Vindhyan area, and the alluvium lies deep on both sides of the river. It seems indeed that the several bands are really less developed. Observations of the felspathic or trappoid beds are very scant, although they are probably to some extent represented. This fact may perhaps be taken as a hint corroborative of others as to the origin of this peculiar rock; it is emphatically most developed in the vicinity of crystalline rocks, as if somehow connected with their detritus. From the Goput, westward, the northern portion of the slate area is profusely affected by granitic intrusive rock, but between this river and the Rehund such intrusions are entirely absent. Shortly to the east of the Rehund granitic rocks become predominant, and here, too, the felspathic beds are largely developed.

The porcellanic beds are found again at Burdhee, and are finally developed in the Amarpoor section, as well as frequently seen between these distant points. In the latter neighbourhood the rock is a white or yellowish-grey porcellanic shale, which seems to have been formed of impalpably fine-grained material, and which frequently shows a minutely sharp lamination. It is also remarkable for a fine jointing in two planes at right angles to that of the lamination and to each other, which thus split the mass into pretty regular little cubes; most commonly, however, rendered abortive by a curious conchoidal jointing, which confuses and obliterates the normal regularity. The only observation of the trappoid rock in the west seems to be in the Mahanuddy, where, a

little distance up stream from the Koteesar limestone, several thin bands of it are interstratified with porcellanic shales. The fact of these bands being only a few feet thick is very strongly against the supposition of the rock being contemporaneous trap.

Between the Rehund and Koel the porcellanic beds gradually pass above into those of ordinary shale and sandstone.

6. Shale and sandstone.

East of Pipia for about eight miles a sandstone is found in a low range of hills dipping north-20°-east at 30°, which constitutes the highest beds of the series occurring south of the Sone in this region. At the mouth of the Ghagur Nuddee is some massive whitish sandstone, to which it seems a similar position in the section should be assigned, as it appears to underlie the shales which stretch along the north bank of the Sone at intervals from this to Jadoonathpoor, where they are lost under the alluvium. At Jaradag they are black and brittle with interstratified layers of sandstone. Immediately below the limestone (7), the beds are green and fawn-colored aluminous clunchy shale.

It appears that at Burdhee, concretionary black shales belonging to No. 8 rest directly on the porcellanic beds, and that Nos. 6 and 7, as well as the sandstone of 8, are therefore entirely absent; a fact evidently connected with the constricted nature of the lower Vindhyan area along here, in which the whole series is undoubtedly thinner than elsewhere. To the west the beds of 6 reappear, and are largely developed along the Mahanuddy. Their general character is that of a black, or greenish-black brittle rock, in beds mostly $\frac{1}{4}$ to $\frac{1}{2}$ an inch thick, but often 6 inches or more. Sometimes they are more indurated and of a yellow color. They are intersected by several lines of jointing, the three most prominent of which divide the strata into regular triangles with angles of 30°, 45°, and 105°. Ripple marking is almost universal. Often, as in the Japamn Nuddee from Bijragoogurh downwards, the entire surface of every layer is covered by rippling, besides which sun-cracks and the marks of rain-drops are very common. All three may frequently be

observed together on a very small slab of stone. Layers and bands of sandstone and also limestone are very commonly intercalated with these strata. Indeed the boundary between the sub-divisions of different mineral characters of the lower Vindhyans is, especially in the west, seldom clearly defined. The arenaceous portions mix with, and fall into, the argillaceous, and each in its turn into the calcareous, the transition being often by slow gradations. In other cases, however, the division is trenchant enough, and the shale, the sandstone, and the limestone are all typically contrasted in mineral and physical characters at their respective ejunctions.

7. Limestone.

No. 7 is the limestone to whose hardness, as compared with the shales above and below, combined with the disturbances which have affected them all, are due the nearly parallel hill ranges which intervene between the escarpment and the Sone, south-east of Bijigurh. At Jaradag it is a most peculiar rock; a confused mixture of compact fawn-colored limestone, calcareous spar, and a small proportion of quartz, as chalcedony, and crystallized. Some layers contain bands of black chert, the cavities in which are lined with rock crystal. Further west the rock is usually fawn-colored, or sometimes light blue, and looks homogeneous in texture on a new fracture, but that it is not so in reality is shown by the rough, honeycombed aspect of its weathered blocks. The bedding averages 2 to 4 feet, and the total thickness at Jaradag is about 40, which gradually increases to 150 feet or so near the mouth of the Ghágur. Beyond this point the limestone we are speaking of is obscured by alluvium for a long distance. It is seen again at Hurma, 10 miles east of Burdhee, about 40 feet being exposed, but at Burdhee itself it seems to be absent from the section. There can be little doubt that the band which runs along the southern face of the Keinjua hills, south of Badanpur, is to be referred to this position in the section, but between these distant points observations are wanting.

8. Shales and sandstone.

No. 8 includes a considerable amount of shales, in the lower part of which there is, nearly always, a thick band of massive sandstone. The shales below the sandstone are quite similar to those of 6, and may equally well be regarded as forming, with them, one sub-division, in which the limestone, 7, occurs as a more than ordinarily thick band. The classification given at page 28 is, it must be remembered, purely a lithological one, framed for convenience in a series where lithological distinctions are generally far from being clearly defined. The sandstone is of trifling importance in the east, and would seem to be absent, or nearly so, at Burdhee. About Rajgur, however, it begins to occupy a prominent place, and thence continues westwards for a distance of 100 miles. All along it caps the Keinjua range, which indeed chiefly owes its existence to the hardness of this rock. In the neighbourhood of Ramnuggur, the Keinjua hills face the Sone with a scarped face almost rivalling in magnitude that of the Kymore range itself. In the extreme west this band of rock dies out, or splits up into minor ones, and in consequence the hills come to an end close to Bijragoogurh. Lithologically the sandstone is very similar to the Kymore. The shales, mediate between it and the limestone above, seem to be constant throughout the Sone valley. Fine sections of them are to be found about Burdhee, where from their black color, they have been mistaken for coal, and pits have been sunk for its extraction. They are remarkable for containing, especially near their junction with the limestone above, numerous calcareous concretions, nearly black in color, very hard and compact, and breaking with highly conchoidal fracture. These include no nucleus, but are sometimes starred by cracks filled with calcite, like septaria. They are not concentric, but finely laminated like the shale itself, although this structure can only be seen on a broken and weathered surface. The normal shape is lenticular or oval, but the molecular force which caused the lime to segregate in any one concretion exerted

a certain amount of attraction on those surrounding it, producing a distortion of shape in them. From this cause the symmetry of form increases with the distance of the concretion from any others. Also, as the quantity of lime is limited, the size varies inversely as the number. They occur of every size, from 6 inches to 3 feet or more in diameter. In many places the layers of shale are found to bend round them more or less, thus furnishing an index to the amount of vertical compression which the rock has undergone since its formation. The strata found in the extreme west are quite similar to these, gradually passing above into limestone. East of Agoree the concretions are absent, or rare, and the junction sometimes perfectly sharp.

9. Limestone.

The next member is the most constant and important of the whole series. It is that exposed in the Doorgowtee valley, being in fact the only lower Vindhyan rock occurring on the north side of the Kymore plateau, save that doubtful conglomerate north of Sasseram (p. 32). From Rotasgurh it may be followed westwards to Mungésur hill. Hereabout it is obscured by alluvium for some miles, but the band which reappears north of Agoree Khas, and which there can be no reasonable doubt is the same, has been traced thence continuously to the western limits of the series. It usually occupies the lower part of the escarpment and the country near the base. Between Mungésur hill and Rotasgurh the whole consists of strata averaging from 1 or 2 to 12 inches or so in thickness. To the north-east the rock is very thinly ($\frac{1}{8}$ to $\frac{1}{2}$ or 1 inch) and evenly bedded, the same layer being generally traceable the length of the section; south-east of Chynepur, for instance, it occurs in strata of $\frac{1}{2}$ to 4 inches, varying in color from light to dark grey, sometimes with a pinkish tinge. It is a hard tough silicious rock, and contains occasional layers of thinly bedded and thinly laminated shales, varying in composition from earthy to highly calcareous. At Budokur, 10 miles south of Sasseram, the limestone is

mostly thin-bedded (¼ to ¾ inches) of a light grey, passing sometimes into greenish-grey and salmon-color, and very fine and even in texture. Many thicker beds are included, which are often semi-crystalline, with irregular seams of calcite. In some places flinty laminæ alternate with those of limestone, and the rock is generally cut up by jointing into small angular pieces. It is in this limestone that the sacred 'Gupta' cavern of the Doorgowtee valley exists, in which the direction of the passages is mainly determined by the jointing, and partly by cracks and fissures in the contorted strata.

Mr. Williams estimates the thickness at Rotasgurh at 700 feet. Near the mouth of the Kunhur it is about as follows:—

7.	Limestone	... ...	150
8.	Shale and Sandstone	... ...	250
9.	*Limestone*	... ...	400
10.	Shale	... ...	150
		TOTAL ...	950

To the west, where these beds spread over the low ground beneath the scarp, it would be difficult to form any reliable conjecture as to their thickness, but they fully maintain their prominent position in the series. Here perhaps the rock is rather thicker-bedded and less pure, more mixed with argillaceous layers than to the east. From Mungésur hill, eastwards, nearly to Rotasgurh, the limestone is covered by shales, which are usually earthy, calcareous in the lower part, and above hard, black, and splintery, and divided by joints into small sub-cubical and triangular pieces. Above these again, and passing into them, another band of small limestone (11) is found in one or two sections. The shales are absent at Rotasgurh and wherever the lower series is exposed on the northern side of the escarpment, the Kymores resting there directly on the Rotas limestone (9). They are further wanting between Agoree and Rajgurh, but are again found

10. Shales.
11. Limestones.

between this point and Rewasin hill (where also the limestone (11) occurs in one or two places), beyond which they vanish from the section till we arrive west of Badanpur. Here there is a considerable development, the typical beds being that hard, black, rock just mentioned; but this seems to become bleached on exposure to atmospheric influences, and hence the strata, as commonly seen, are white, sometimes striped with brown, very fine-grained in texture, laminated, sometimes hard, and then much resembling the porcellanic beds, sometimes disintegrating to an impalpable powder.

Stratigraphy.

The amount of disturbance which the lower Vindhyan series has undergone is great. The general result has been to give the whole a northerly inclination, and this inclination increases in amount from north to south. Thus the lower beds near the slates are not unfrequently thrown up vertically, or even doubled up; but as we approach the escarpment the strata are observed with a moderate inclination, that is to say, *general* inclination; for the whole series from top to bottom is subject to violent and capricious contortions on a small scale. Fig. 3 shows an instance of such amongst the shales (No. 10) close under the scarp.

Fig. 3. Local contortion in shales.

Fig. 4 represents another case in the Rotas limestone near Rewasin hill, which may be taken as a typical example of the stratigraphy of the

Fig. 4. Local contortion in limestone.

series. Wide sheets of rock are frequently found with very slight dip when a short abrupt bend is come upon, the beds within a few paces resuming their usual arrangement. In other places the strata form a series of undulating anti-and syn-clinals, or the whole may be locally crushed up in confusion. The axes of contortion are generally, when considerable, marked by lines of brecciation. The breccia is different in aspect from that of the older rocks, exhibiting a less complete mineralization of the mass, and retaining the appearance of infiltration, with many half-filled cavities. The cementing material is silica or lime, the latter when the crush is amongst calcareous rocks. In consequence of the decreasing dip from south to north, which is more marked in the upper part of the valley, the higher members of the series generally occupy a disproportionately large area.

Thickness.

It is difficult to arrive at any very reliable estimate of the total thickness of the lower Vindhyans on account of their disturbed state and the want of good vertical sections amongst the bottom beds; but allowing for such elements of uncertainty, it seems that we are not likely to err very grossly in assigning to them a thickness of 2,000 feet in the region east of the Rehund.

Every consideration, physical, stratigraphical and lithological, supports the conclusion that the 'Semri' rocks of Bundelkund are the same series as the 'lower Vindhyans' of the Sone valley. The same certainty, however, no longer obtains when we descend to the sub-divisions of the series and attempt to correlate those of each locality. Such indeed can hardly be expected when we remember the distance between the northern and southern outcrops and the vagueness of many of the sub-divisions in either one of them. In both districts we find a considerable development of sandstone at the base of the series and the most important limestone* near the top, but it would be unsafe to assert

* Memoirs, Geol. Surv., India, Vol. II, p. 6.

that even these were representative. The general lithology is, however, strikingly similar. For instance, the shales, No. 10, are identical in appearance with the Pulkoas. Both in their natural state are black, very hard, and cut up into little cubes by jointing, and become white and partially disintegrated by weathering. Very much the same as this are the black shales of Burdhee and of the Boghin valley* which, it may be remarked, have both been mistaken for coal, and attempts made to work them. The general aspect of limestone, sandstone and shales is the same in both, being distinguished by a thin-bedded, flaggy structure, and frequent rippling, and the tendency of the members to graduate into each other. Certain varieties of rock, however, seem confined to one district. Such are the Tirhowan breccia, and the trappoid beds, so far as we know.

Boundaries.

Except one or two doubtful cases of local breaks, to which allusion has been made when speaking of the bottom sandstone, the southern boundary of the lower Vindhyans is a natural one throughout from Rotasgurh to the Mahanuddy. West of this stream the junction is marked by the commencement of a great fault, to be described hereafter, which extends a long way down the Nerbudda valley. Outliers, sometimes of large size, are not unfrequently found scattered over the slate area to the south, these being, it appears, always made up of the bottom sandstone alone, which there attains a greater thickness than anywhere in the main area .The outliers generally assume the form of narrow longitudinal ridges, parallel with the strike, and are distinguishable by their contour from hills of older rock. Inliers are very uncommon and of small importance. One such at Sulkhun, north-east of Agoree Khas, owes its existence to a small anticlinal, by which the lower beds are brought up. At the bend of the Mahanuddy, at Koteesar, there is another case where a low hill of most peculiar

* Memoirs, Geol. Surv., India, Vol. II, p. 92.

quartzite associated with mica-schist makes its appearance in the area of the more recent formation.

The northern boundary is also natural, being formed by the junction of the lower with the upper series. The junction is, of course, parallel with the strike, and the latter, making a sudden bend to the south near Belheri, brings the boundary at right angles against the Nerbudda fault, which thus sinks the lower series completely out of sight. Its only reappearance to the westward is north-east of Kuttungee, where it occupies the centre of a great anticlinal bend, marked on both sides by ridges of Rewah sandstone.

Relations to Upper Vindhyans.

The best sections exhibiting the junction of the upper and lower Vindhyans are to be found in the Doorgowtee valley and its lateral gorges. In all cases the Kymore sandstone rests, as far as the individual section is concerned, perfectly conformably on the Rotas limestone, which there occupies the highest place in the lower series. Thus in one place where the junction is exposed for 150 yards, a particular bed in the limestone, about 8 inches beneath the Kymores, is traceable all along. Other instances might also be given. This evidence, however, being somewhat of a negative character, cannot be taken as conclusive with regard to the whole area, and there is some reason, on the other hand, to suppose a slight unconformity. It will have been observed that the shales, No. 10, and limestone above, are very inconstant in their occurrence, sometimes attaining a thickness of 300 and 400 feet, while absent entirely in other places. The explanation of such capriciousness that first suggests itself is a slight disturbance and denudation anterior to the deposition of the Kymores, and it is quite possible that such is the true one. But, on the other hand, a tendency to lateral alteration in mineral character has often been observed in the upper beds of the series, by which strata, which in one locality are limestone, change to shale in another. The idea that the variable occurrence of the shales, No. 10, and limestone, (11) should be accounted for in this manner, is strengthened by the fact

that, in the eastern region where they are best seen, the three upper members of the series taken together present a tolerably uniform thickness; where the shales are most largely developed the limestone is thinnest, and where the former is absent, the limestone alone maintains the full thickness of the three elsewhere. If there *be*, however, any disturbance unconformity between the two series, it is so very slight as to be inappreciable; but that the lower was more or less *denuded* is amply proved by the abundant fragments of its strata frequently observed in the lower beds of the upper. Such would seem to indicate a certain break between, which coupled with the sharp line of division which everywhere obtains, and the great change in mineral character and stratigraphy, furnish ample reason for the separation of the two into an upper and a lower series. The strata of the lower are, as a whole, *calcareous* and argillaceous, of the upper *arenaceous* and argillaceous, and while much of the upper are thick-bedded and massive, flagginess is a prominently characteristic feature of the lower. The sub-divisions also of the upper are, in the same amount of rock, generally fewer and thicker. In other words, the conditions of deposition change oftener in the lower during the formation of an equal amount of strata.

As there is little or no unconformity, the general and often violent disturbances existing in the lower series are of course subsequent to the whole Vindhyan formation, affecting, as they do, the Kymores as well as the beds beneath, and gradually becoming less in the upper portion of the series which was less exposed to the disturbing forces acting from below. The thin-bedded, flaggy nature of the lower Vindhyans no doubt favoured the production of those complicated contortions on a small scale which we find there, and which the massiveness of the Kymore sandstone would forbid. The bends of the latter are on a bolder scale, and it is a remarkable fact that, however crumpled the lower series may be, the strata immediately subjacent to the Kymore sandstone assimilate themselves to it, and are found in even and unbroken layers.

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Chapter VI.—The Upper Vindhyans.

The upper Vindhyans cover a much larger spread of country than the lower. The latter, as has been seen, are overlapped near Ságar and Jubbulpur, west of which they do not exist, and where they do exist to the east, it is only at their outcrops from beneath the upper series that they appear at the surface. Taken generally, the upper Vindhyans are made up of several thick masses of sandstone with alternations of shale, which in lithological characters frequently preserve a remarkable uniformity over immense areas. At a distance of several hundred miles, the same sub-division can often be recognised in an instant by the peculiarities which distinguish it elsewhere. The calcareous element is deficient, being only represented by a single limestone of importance. Evidence of the shallowness of the depositing waters is furnished by the presence of beautiful ripple-marking on the surface of bed after bed for hundreds of feet in thickness, and in other cases by the amount of false-bedding which distinguishes certain bands. With the exception of certain obscure markings in the Bundair limestone, and which are probably inorganic, no trace of fossils has hitherto been found in the Vindhyans, whether upper or lower, a fact which has frequently been alluded to with surprise by former explorers, who have remarked the apparently highly favourable nature of the rocks for the preservation of such memorials of former ages.

The stratigraphy is very simple on the whole, the various bands being spread out nearly horizontally over wide areas, and it is only in a few special regions of disturbance that the geology is at all complicated. Such are the upper part of the Nerbudda valley, where the rocks are faulted, thrown up vertically, and even inverted; the Dhar forest; and the northern boundary south-west of Agra. In the eastern extension of the formation the strata are disposed in the form of a very shallow basin, in consequence of which the highest members of the series geographically occupy a central position and are surrounded in

succession by the older sub-divisions. This basin-form is, it seems, intimately connected with the original conditions and area of deposition, which question with regard to the northern side has been discussed in a previous volume of the memoirs.* The boundaries which are nearly everywhere natural, are sharply defined, the outliers, although pretty numerous, being small and close to the main boundary. The chief regions of faulted junctions are the Nerbudda valley, and that south-west from Agra. As a whole, the formation, notwithstanding its antiquity, is not much altered. The lower sandstones, however, are not unfrequently more or less vitrified, or even converted almost into quartzite, as in the Dhar forest; and the shales more or less indurated: the upper members, the Bundairs, seldom betray any sign of change.

The formations which overlie the Vindhyans are of comparatively recent date. Thousands of square miles are obscured by trap, but the great Indian carboniferous series, intermediate in age, are nowhere found in superposition. Such evidently never existed there. The unaltered condition of the Bundairs would seem to indicate that they never have been subjected to great superincumbent pressure which has more or less affected the lower groups of the formation.

(a).—Kymore Group.

Lower Kymores.

The Kymores attain their greatest extension, horizontally and vertically, at the eastern end of the Vindhyan area, and it is here especially that the lower sub-group is developed, which, however, is of small importance compared to the upper. It may be studied best along the course of the Ghágur near Bijigurh fort, the broad shallow valley of which has been scooped out of the shales, which crop out in the scarp at either side, and on the flanks of the imposing hill from which they derive their name. Fine sections are also obtainable in the Doorgowtee valley. South-east

* Vol. II, p. 57.

of Kudhur the black shale (Bijigurh) rests directly on the Rotas limestone, while the lower sandstone intervenes in other localities, attaining at Bijigurh a thickness of 200 feet or more. The lowest beds of the Kymore group, therefore, must have been deposited rather irregularly, or in patches. This is also indicated by the existence of lower Vindhyan debris 100 feet or more from the base of the upper series, as when this thickness of strata had been formed in one place, the lower rocks must have been still exposed in that whence the debris was derived. The lower Kymore sandstone appears to attain its maximum thickness near Bijigurh, thinning out from this both east and west. At Burdhee where the shales become extinct, and beyond which the lower sandstone can no longer be distinguished from the upper, it is much thinner than at Bijigurh.

The thickness of the shales at the latter place is 150 feet or so, and about the same in the Doorgowtee valley. A section in one of the lateral gorges exhibits 'pencil' shales, quite black and intensely brittle, covered 2 or 3 inches deep with minute sharp-pointed fragments. They are intersected by joints which have a rusty appearance from decomposed pyrites, and some are marked by veins 1 or 2 inches thick of the impure mineral; the shale itself often weathers red from the same cause. A little higher up the stream the latter are mixed with a large proportion of black and dark-colored sandstone; the shale on the weathered surface is perfectly black, and looks exactly like impure coal. In general it consists of bands of pure shale and thin-bedded shaly sandstone. The passage into the upper sandstone is sudden, the beds being generally interstratified for 2 or 3 feet at the junction. It was these shales which were mistaken for *coal* at Bijigurh,* and originated the rumour of the existence of that mineral in the Kymore hills. Owing to their pyritous nature, efflorescences of sulphate of iron and alum are common, and have been economised to a small extent.

* Ante p. 8.

East of Bijigurh and Chynepur the shales, if not seen in the scarp, are generally indicated by fragments in the water courses, and it seems that they are everywhere represented, sometimes by one thick band, sometimes by several alternating with sandstone. They are not found however at Sasseram or west of Chynepur, either from their dying out, or sinking below the alluvium level. Should the latter be the cause, it would preclude the hope expressed by Mr. Williams of limestone being obtainable at Chunar at a workable depth. To the south they are traceable westwards as far as Burdhee, making themselves apparent by the influence they exert on the contour of the scarp. It is double where they exist, but becomes single after their extinction.

Beyond this point the escarpment is much obscured by talus, and sections exposing the lower portion of the Kymores are very rare. The only beds yet observed referable to the lower sub-group are some about 10 miles west of Badanpoor, where, at the base of a little waterfall dry in the cold season, some 30 feet of hard silicious shales occur. The beds, of greenish, greyish, and reddish tints, are some finely laminated, others two or three inches thick. Lithologically these bear little resemblance to the Bijigurhs, but their position beneath a band of conglomerate, to all appearance representing the Kymore conglomerate, which rock forms the base of the upper sub-group, renders their connection with the lower most probable. In the same position we must include the fine crumbling yellow shales mentioned by Mr. Medlicott as occurring near the river Kane in Bundelkund* and which are the only lower Kymore beds yet known west of Allahabad.

Upper Kymore to the east.

In the eastern part of their extension the upper Kymore sandstones (as well as the lower sub-group) are subject to a considerable amount of disturbance; more than

* Mem. Geol. Surv., India, Vol. II, p. 59.

would be suspected from a traverse merely of the table-land. It is in the deep river-gorges that sections are to be found clearly exhibiting such, the large bends of the massive sandstone contrasting with the small scale contortions of the flaggy Rotas limestone. These disturbances, however, are never excessive, a dip so high as 40° being unusual. Faults of slight throw are of rare occurrence, the most important met with being that by which the limestone of Kurumchut is cut off on the west side. East from Mungeysar hill the strata everywhere dip *in* to the scarp, or north. In the valley of the Ghágur, there is an anticlinal which brings the limestone some 3 or 400 feet up the side of the scarp east of Sulkhun, while north and south of this the Kymores appear at the bottom. It is probably the same undulation which brings up the lower Vindhyans in the Doorgowtee valley in a line running east-20° north. West of Sulkhun the dip in the scarp is again north, and at Kurumchut the lower series re-appears. Thus the strata in the southern part of the table-land east of Burdhee seem to form a certain number of undulations running a little north of east. These straight ridges must have had considerable influence in preserving a straight line of scarp during its denudation. The lowest portion of the sandstone near the Bijeygurh shales is very impure and argillaceous, of a blackish green color, and rather thin-bedded. This rock is sometimes separated sharply from the greyish-white and quartzose true sandstone. The mineral character of the latter varies much. Sometimes it is coarse and conglomeritic; in other instances, micaceous. Usually it is fine-grained, especially along the northern scarp by Chunar and Allahabad, where coarse beds are never met with. Here it is usually greyish and yellowish white or reddish; sometimes speckled brown. False-bedding is frequent, though far from being so much developed as in the Rewahs to the south, where it is almost universal. Sometimes the rock is somewhat shaly as

exemplified in the following section seen in the face of the hills south of the Jumna (ascending) :—

			Feet.	Inches.
(a.)	Two beds hard sandstone	... ...	3	6
(b.)	Oblique, false-bedded flags	... ...	1	6
(c.)	Ditto, with some thicker horizontal beds	... ...	7	0
(d.)	Shaly sandstone	... ...	3	0
(e.)	Very sandy micaceous shale	... ...	2	0
	(*d* and *e* remarkably regularly bedded, layers $\frac{1}{8}$ to $\frac{1}{4}$ inch).			
(f.)	Compact sandstone	... ...	3	0
(g.)	Very sandy shale or shaly sandstone irregularly bedded	...	1	6
(h.)	Compact sandstone	... ...	2	0
(i.)	Sandstone more or less shaly	... ...	2	6
(j.)	Rather coarse soft yellow sandstone, greatly false-bedded	...	9	0
(k.)	Ditto, very soft	... ...	3	0
(l.)	Compact, nearly white sandstone	... ...	20	0
			58	0

The bedding on the whole is of moderate thickness, but very massive beds are abundant. North of the boundary with the Rewah group the rock is generally rather coarse, of a yellowish-white color, and very commonly stained in patches to a dark brown by iron. The maximum thickness of the Kymores is in the extreme east, Captain Sherwill estimating them at Rotasgurh at 1,300 feet. How much more they originally were it is impossible to say, since they are there covered by no other beds; tracing them along the escarpment we find them reduced at Rajgurh to 6 or 700. A magnificent section of them is exposed in the deep narrow gorge through which the central portion of the Adh valley drains to the Sone. Some portions of the bedding are of great massiveness, and the sides of the gorge are in many places perpendicular walls, caused by a well-marked system of joints running N.-10°-W. Here as in other places those peculiar little ridges produced by the filling in of joints or mud-cracks, are exhibited in great perfection.

All along the Kymore scarp the sandstone dips inwards at 10° or 12°, the inclination seldom exceeding 20°, or being less than 5°. This

dip is participated in by the Rewah group, but gradually dies out to the north, and at a few miles from the scarp the strata are usually nearly horizontal. From the general hardness and massiveness of the Kymore sandstone, it gives rise to very bold precipices and 'headlands,' as may be seen anywhere east of Rewasin hill. In the other direction the sandstone becomes thinner and the outline of the scarp less bold. West of Badanpur it is reduced to less than 150 feet, and the Lower Vindhyan inliers, north-east of Kuttungee, are in contact with the Rewah sandstone.

Possible development in Nerbudda valley.

It is, however, by no means certain that this extinction is final. In the Rewah country the upper Rewah sandstone is but a few hundred feet thick, while the accumulation of sandstone in the Nerbudda valley, which we have colored as belonging to that group, is several thousand. Now, as the lower Rewahs die out west of Badanpur, and there is no marked lithological difference between the upper Rewah and the Kymore sandstone, it is quite possible that those rocks in the Nerbudda valley, near Hoshungabad and Burwai, include *both*, although we can no longer distinguish them. There are indeed bands of shale met with (as west of Jamghur and at Mehalpur) which may represent the lower Rewahs, although their lithology, which is the only guide we have to go by, is not sufficiently strongly marked to express a decided opinion either way. There is nothing improbable in supposing the lower portion of the Nerbudda sandstones to be Kymore. It would merely indicate that the overlap in the neighbourhood of Bilheri, is *local*—a case, which would be perfectly analogous to one of which we have indubitable evidence, the dying out of the lower Rewahs near Hutta, their complete overlap north of Ságar, and their revival in the Gwalior country. There is again the instance of the lower Kymore sandstone west of Burdhee which we know exists, but which cannot be distinguished from the upper on account of the absence of the Bijigurh shales. In connection with this it is perhaps

worthy of mention that the lower Vindhyans which can be easily recognized by their lithology and which become finally extinct near Kuttungee, also become finally extinct north of Ságar, while the Kymores are continuous up to Gwalior; that difference between them on the north favours the idea of a similar difference to the south; and taking the very constant applicability of the threefold division to the upper Vindhyans elsewhere, as along the whole northern and western boundary down to Neemuch, into consideration, the likelihood would seem to be that the Kymores *are* represented in the Nerbudda Valley and that such are the lower strata of those vast accumulations of sandstone by Hoshungabad and the Dhar Forest.*

Kymore conglomerate.

About 10 miles west of Badanpur between the shales mentioned above (page 51) and the sandstone, 4 or 5 feet of conglomerate occurs, composed of ferruginous, almost hæmatitic pebbles, the largest about four inches diameter, and others of quartz. The former are far the more abundant; the remainder of the rock being of finer ferruginous materials. This is the only recorded observation of the Kymore conglomerate on the southern edge of the Vindhyans. It is very rarely that one obtains a view of the base of the Kymores along the upper Sone Valley, but to the east where some sections are procurable, the rock is certainly unrepresented. It is however largely though unequally developed in Bundelkund† where it behaves like a shore deposit in attaining its greatest thickness at the edge of the escarpment and thinning out to the south, as seen in river gorges. In this respect it resembles the base conglomerate of the lower Vindhyans in the Sone Valley, and both are supposed to be littoral beds approximately marking the original limits of deposition. On Pulkoa Hill‡, near the river Kane, the rock is composed of well rounded pebbles, mostly from ¼ to 1 and 1½ inches diameter, the largest seldom exceeding 3: the vast majority are of bright red jasper; the remainder of dark purplish jasper; a smaller num-

* See page 77. † Vol. II, page 28.

‡ Where it overlaps the Kymore shales: Vol. II, page 59.

ber of yellowish jasper, and an occasional one of white quartz. The bulk of the pebbles far exceeds that of the matrix.

From Bundelkund to Gwalior the conglomerate appears to be seldom entirely absent, being, if not more strongly developed, at least represented by a band of conglomeratic sandstone. In the latter country owing to the uneven surface on which it was deposited, it is sometimes absent on the higher ground while occurring in thick masses in the hollows. An instance of this may be observed under Gwalior Fort and the hills adjacent. The Kymores were deposited in a hollow of the contemporaneous trap of the Gwalior series, and the conglomerate which is

Fig. 5. Section through Gwalior and adjacent hills. *a*, Kymore sandstone: *b*, Kymore conglomerate: *c*, Trap, *d*, Jasper beds—Gwalior series.

found thickest at the lowest level is entirely wanting at the highest. (Fig. 5). On the hill about a mile north, the Gwalior rocks reach nearly 100 feet above the plain and there is no conglomerate, but on the same hill a short distance eastwards, the Gwaliors are at a far lower level and the conglomerate is well developed. The latter is seldom more than 10 or 15 feet thick and mostly confined to one band; but in places, as between Kuraya and the Par scarp, irregular bands of it alternate with beds of sandstone, as exemplified in the following section.

Gneiss.	Feet.	Inches.
(a.) Irregular bands of angular jasper conglomerate, interbedded with fine white sandstone	6	0
(b.) Conglomerate—very water worn pebbles, mostly jasper ...	1	0
(c.) One massive bed of coarse sandstone containing a few jasper pebbles	3	0
(d.) Fine sandstone	1	6
(e.) Coarse sandstone containing numerous angular pebbles of jasper	2	0
Upper Kymore sandstone.		

The same evidence of littoral deposition is observable in Gwalior as in Bundelkund. At the entrances to the many gorges which run in westwards from the face of the escarpments, the conglomerate is 6 or 8 feet thick while half a mile from the mouth it is nearly or quite extinct. The rock is formed of pebbles of the banded jasper and hornstone of the Gwalior series. Under Gwalior Fort where it rests on trap some decomposed pieces of the latter are included. In most places the pebbles are very angular and show no traces of having been waterworn or brought from a distance. Now in Bundelkund they are completely rounded and can be closely identified with no rock in the Bijawurs* or other formations of that part of the country, while they are undistinguishable from the red jasper of the Gwalior series. Whence they came it is hard to say. The nearest Gwaliors we know of are those of Gwalior itself.

The Kymore sandstone is very irregularly and thickly stratified, the beds ranging from two to ten feet in thickness. On the Pichour outlier are masses thirty feet thick without joint or bedding. The rock is generally very fine-grained and hard, white or pinkish in color, with minute specks of felspar. The upper surface is very uniform, but the lower, from the uneven floor of deposition, quite the reverse. Hence, (not from subsequent denudation) the total thickness varies greatly, being in some places reduced to a few feet, in others exceeding 300.

A most interesting section, illustrating at once this and the unconformity of the Vindhyans to the Gwaliors, may be seen at the point where the Par and Kymore escarpments meet each other at right angles. The Par is something under 200 feet high, of which the lower 150 is gneiss, capped above by the Par (Gwalior) sandstone; two hundred yards from the junction of the scarps, the Kymore has about the same elevation and the same amount of gneiss, but the latter suddenly drops nearly to a level with the plain, and the hollow thus formed is filled by the

* Mem. Geol. Surv., India, Vol. II, page 28.

Kymore conglomerate which abuts against and covers the rocks of the Par scarp.

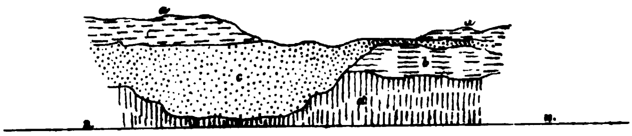


Fig. 6. Junction of the Vindhyan and the Par scarps, near Doorserai. *a*, Kymore sandstone: *b*, Par sandstone: *c*, Kymore conglomerate: *d*, Gneiss.

It is clear that the conglomerate was deposited against a nearly vertical bank of gneiss and Gwalior sandstone; that the latter at the beginning of the Vindhyan epoch extended no further south than it does now; in fact that the present Par scarp existed, and was little different to what it is to-day, *before the commencement of the Vindhyan formation.* This is by no means an isolated case. It is impossible to pass along the junction without being struck by the marked unconformity between the two series, and the extensive denudation which the older had undergone, by which the principal physical features of the country now existing, had been carved out before the deposition of the newer.

If we follow the Kymore scarp northwards, the Vindhyans are seen resting on every member of the Gwaliors in succession from the lowest to the highest.

About a mile east of Bustori (north-east of Antree) there is a large outlier of Kymore sandstone (Fig. 7.) which stretches across and nearly fills one of the valleys in the Gwalior series. It is about 100 feet high,

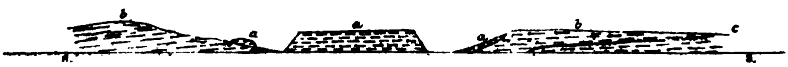


Fig. 7. Section near Bustori. *a*, Kymore sandstone: *b*, Jasper beds of Gwalior series: *c*, Par sandstone.

in form &c. presenting all the usual appearances of such outliers, and composed of massive very irregularly bedded sandstone to the very base, which

is some 150 feet below the tops of the hills on either side of Gwalior rocks. Even the summit of the outlier itself is below that level. A more beautiful instance of pre-existing denudation and ancient valley erosion could scarcely be found than this. Similar outliers of smaller size are frequent in the neighbourhood, filling up lateral valleys, as this does the main one.

While speaking of outliers those at Ladera and Pichour should not be omitted, as they illustrate the former extension of the Vindhyans to the eastward. Occurring south of the Par scarp, both rest on gneiss, the former abutting against the Gwaliors. The Kymore conglomerate is represented here, although it is not seen between this and the main scarp, an interval of twenty miles. Such evidence of eastern extension is not found elsewhere, and here it somewhat complicates the question as to the original limits of the conglomerate.

North-west boundary.

We find the Kymores again along the north-west boundary. Six miles north of Futtipur-Sikri there is a small hill which is no doubt the last remnant of a ridge which once stretched to the south-west. It is composed of the Kymore sandstone which dips south-east at 15° and clearly underlies the Rewahs and Bundairs of the Futtipur ridges. South-west from this point the Kymores do not show above the alluvium till we arrive south of Hindoun, where there is another hill of them surrounded by alluvium between the Bundairs and the Gwaliors. About twenty miles north of Hindoun near the town of Neethehar there are two small hillocks of the breccia mentioned below, dipping north-west at 60° and isolated in the alluvium. They are too small to show on the map, but are of importance as indicating the former extension of the Vindhyans. To the south-west of Kerowlee the Kymores occur in considerable force and in a somewhat intricate manner. From Kerowlee westwards the 'quartzite series' and the Bundairs are brought in contact by a great fault which has not yet been traced

to the south-west. North of the quartzite sandstones and resting unconformably on them are 300 or 400 feet of a very peculiar breccia which would appear to represent the Kymore conglomerate, although it is lithologically very different from that rock as seen in Gwalior and Bundelkund. It is far more like the 'hornstone breccias' of the Bijawur series, and still more resembles the Tirhowan breccia, but the upper part of it becomes conglomerate and contains undoubted pebbles derived from the Gwalior series imbedded in a sandstone matrix. The upper portion of the breccia also was observed in one place (where the conglomeratic part did not exist) to alternate with the lower beds of the Kymore sandstone. The breccia in some places is obscurely bedded, but it generally occurs in great masses devoid of any structure. It presents some variety in appearance. It is often seen as a compact silicious rock very peculiarly banded. The bands are very fine and irregular, and twist about in all directions; the rock at the same time often containing small cavities lined with quartz crystals. In other cases the laminæ are quite parallel and regular. In others again the rock is yellow and the laminæ broken and twisted. In another kind numerous angular fragments of a white finely-laminated silicious rock, very similar to the first variety, are imbedded in a compact yellow silicious matrix. Similar fragments are also found imbedded in a white sandstone matrix. Again in places undoubted Gwalior pebbles are found, much altered, mixed with quartz pebbles and imbedded like the last in an arenaceous matrix.

In no place are all these varieties seen in one section, and that containing the Gwalior pebbles is less constant than the others. None of them appear to admit of any separation; they pass into each other imperceptibly; for instance near Thom, the conglomerate containing Gwalior pebbles, although here only a few feet thick, is better developed than anywhere else. The pebbles are altered and become more like red quartzite, although still retaining the structure of the Gwaliors. Below this

are pebbles of red quartzite, most probably more-altered fragments of the Gwaliors. Again in the hills north of Chuli it is impossible to separate the Kymore sandstone from the breccia, the two rocks being interbanded. The latter is here not of the pebbly variety, but of the more altered kind which is generally seen lower in the section. It is observable that the Kymore sandstone is far less (if at all) altered when it rests on the pebbly variety of the breccia than when resting on the more silicious or compact variety.

The entire thickness of the Kymore sandstone here seems to be very considerable, although, from denudation and alluvial covering, more than fifty feet are seldom exposed.

The stratigraphy of the Vindhyans here will be best comprehended by comparing the accompanying section with the map, which latter however does not, from its small scale, admit of details being introduced. The strata are disposed in two synclinal troughs, (Fig. 8) the intervening anticlinal having been denuded away. The harder beds, namely, the Kymore sandstone and breccia, the lower Rewah and the upper Rewah sandstones, form a number of parallel ridges running north-east—south-west; but the softer beds, the Punna and Jheeree shales rarely show above the alluvium which occupies the ground between each ridge. The corresponding ridges of the south-eastern synclinal curve round and join at the south-west end of the trough and approach each other somewhat to the north-east so as to bear some resemblance to a lengthened horseshoe. The quartzite series underlying the Kymore breccia is brought against the Bundairs on the south-east by the great fault, and is also observable along the outer side of the north-west synclinal, in the portion to the west of the section. It also makes its appearance above the alluvium in two or three places under the Kymores along the sides of the denuded anticlinals. The centre of the north-western synclinal is occupied by lower Rewah sandstone, but the south-eastern includes the still higher upper sandstone.

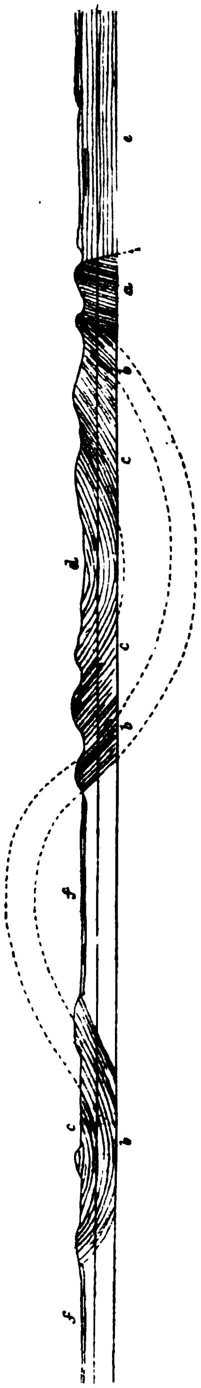


Fig. 8. a, Quartzite Series: b, Upper Kymore: c, Lower Rewah: d, Upper Rewah: e, Upper Bundair: f, Alluvium.

Western extension.

With regard to the detailed classification of the Vindhyans in their western extension, our information is as yet imperfect. In the Neemuch country, however, there are three great bands of sandstone separated by two great bands of shale, the uppermost of which is divided by a strong bed of limestone. There can be scarcely a doubt that the lowest sandstone represents the Kymore, which is thus present at the extreme eastern and extreme western limits of the formation.

(b).—Rewah Group.

Lower Rewah to the east.

The junction of the Kymores with the Rewahs is sharply marked. North-west of Adesar hill the Adh river forms the boundary between them for some distance, and here good sections are obtainable, showing the lower part of the shale as well as the junction with the sandstone. Thus west of Jurkour about 20 feet of hard flaggy green shales are covered by earthy red shale, and rest on not very fine sandstone (Kymore) stained reddish brown by iron, and containing brown and greenish-brown ferruginous clay galls. The junction is perfectly sharp. No layers of sandstone occur in the shales. Again, 2½ miles north of Jurkour in the same stream, a similar section is exposed, the shale beds for the bottom foot or so undulating with the uneven surface of the sandstone, and above perfectly even. In a stream south-west of Adesar hill both rocks are

considerably contorted and rolling sharply, as if from lateral pressure. The sandstone in contact with the shales occurs in beds 6 to 9 inches thick, lower down in flags. At Byhera Dabha in the Adh valley, resting on the usual uneven beds of the Kymore sandstone, are 20 feet of greenish grey splintery shales. Above this the sequence of the beds is greatly obscured by several small slips, and nowhere is a continuous section seen, but the following would seem to be the order. Above the strata just mentioned is about an equal thickness of thinly laminated red shale containing bands of very calcareous shale or impure limestone and covered by 10 or 12 feet of an impure limestone in beds ½ to 1½ inches thick, but divided into thin laminæ by minute layers of calcite. At Badanpur ghát the highest beds of the Kymore sandstone are hard and compact, greyish-white and reddish, the top bed containing rolled quartz pebbles up to 1½ and 2 inches diameter. Resting on this are alternate layers of arenaceous shale and impure earthy sandstone (2 to 9 inches thick) slightly contorted; in thickness

	Ft.	In.
about	12	0
Red earthy shale with a little green and a few arenaceous layers...	10	0
Blank...	6	0
Green shale, mostly earthy, partly arenaceous, with a little red, sandy layers 1 to 8 inches thick	8	0
Greenish and greyish white aluminous shale with arenaceous seams	8	0
	44	0

Above this is talus-covered.

The preceding sections show the lowest part of the Punna shales to consist of—

	Ft.	In.
Red and green silicious shales about	20	0
Earthy red shale	20	0
Impure shaly limestone	10	0

This limestone is absent in the western part of the Rewah scarp. South-west of Rewah the lowest beds comprise nearly 100 feet of red earthy shale without any limestone, although it is slightly calcareous near the bottom. At Badanpur there is none either.

In the Chula stream north of Adésar hill the bottom shales are well exposed, being perfectly horizontal, in very thin laminæ, very regularly bedded. Where the rock is polished by water it exhibits a ribboned alternation of red and yellowish- or greenish-white bands, the red predominating; the highest beds seen are the lower part of the calcareous portion. Two miles west of Kuttra ghát at the foot of the scarp, the shales are red, breaking up on the surface into small flakes. Interstratified with them are thin yellowish calcareous sandy layers. Below this is some 15 feet of a thin-bedded impure kind of limestone made up of minute alternate layers of calcite and reddish silicious limestone. The softer laminæ weather away on the surface and give the rock a jagged appearance. These sections of the Punna shales may be taken up at Ginga hill where the lowest beds seen are the calcareous. The following section is one observable in a small hill west of Ginga, ascending—

	Ft.	In.
Yellowish sandy thin-bedded shales	25	0
Red shale	0	4
Green ditto	0	4
Red ditto	0	4
Sandy yellow shale	2	0
Red and green shale	1	6
Green shale, sandy and slightly greasy	11	0
Alternations of green and red	2	6
Green with thin layers of red, more argillaceous, less sandy ...	14	0
Semivitrified sandstone	0	4
Hard silicious green shale	8	0
Red and green shale	3	0
Fine green shale (more argillaceous)	12	0
Hard silicious greenish shale	60	0
Similar shale, green, some beds reddish	38	0
blank, including remainder of Punna shales and lower part of lower Rewah sandstone	118	0
Total ...	296	0

The Punna shales are chiefly thin-bedded, very regular and undisturbed and divided by sharp joints; below the calcareous band mostly

red earthy, above more or less hard and silicious, the prevailing color being a greenish grey. The Jheeree shales are less regularly bedded, softer, and mixed up with numerous layers of soft earthy sandstone. To the east, however, where the intermediate sandstone is wanting, no line can be drawn between them ; the passage from the Punna group to the sandstone above is seen in the spur west of Sohagi ghát. Above the mass of the Punna shales there is a blank of 12 ft. and then—

	Ft.	In.
Green shale, considerably broken	2	0
Irregular bed of brownish sandstone	1	0
Mixed shale and sandstone	1	0
Thin-bedded, rather soft yellowish sandstone	4	6
Thick-bedded, massive grey sandstone containing a few quartz pebbles	13	6
Total	22	0

The lower Rewah sandstone is absent in the extreme east, and is first observed in the outliers south-east of Burokur Khas, where, although less than ten feet thick, it is apparent as a dark line at a uniform level round all the hills. Near Sohagi ghát this rock is 25 feet thick, occurring in fine massive beds, hard, and often more or less vitrified. The frequency of pebbles and sometimes small clay-galls is characteristic. About the debouchure of the Tonse, where this sandstone is sunk to the foot of the scarp, it covers a considerable area.

The junction of this sandstone with the shales above it is sharply marked. Thus at Ginga hill resting immediately on the former is 120 feet of rather irregularly-bedded shale, greatly cut up by small jointing; of yellowish-brown and green colors, the latter variety composed of fine green clay with a slightly greasy feel and conchoidal fracture. The other beds are arenaceous, sometimes almost sandstone, and layers fully deserving this title are not uncommon. This lower portion of the Jheerees is everywhere pretty much the

same. At Keraha, south-east of Rewah, they are contorted and rolling on a small scale, made up of thin beds of sandstone with short lenticular layers of greenish-white and dark red aluminous shale. From the talus-covered nature of the escarpment, sections are rarely found of the upper beds. At Dibhur ghât, however, one is obtainable, showing below a considerable thickness of greenish and greenish-brown shales with layers of impure sandstone; these pass into a red earthy rock, sometimes hard and breaking with a conchoidal fracture and sharp edges, in beds up to 2 or 3 inches, but shattered by jointing in every direction, similar to *(b)* in the following section. Other parts are softer and in thinner beds. In this part of the sub-division occurs a large amount of greenish-white and red aluminous shale. The intercalated beds of sandstone found below are absent higher up. The top beds and their junction with the upper Rewahs may be well observed at the falls of the Goorma nuddee south of Burokur Khas :—

	Ft.	In.
a.—Hard silicious green shale with a few specks of mica, and great numbers of small clay-galls of the same color, which cause the rock to split with a rough uneven surface: seen	1	0
b.—Dark red shale with red streak, very brittle, conchoidal fracture; beds up to 6 inches, irregular joints, N. 20 W.	12	0
c.—Similar rock, but green	0	5
d.—Semivitrified sandstone	0	9
e.—Green shale like *c*	0	6
f.—Reddish grey semivitrified sandstone passing into a hard green rock like *a*	0	9
g.—Green shale like *c*	0	8
h.—Hard silicious green shale like *a*	0	6

Resting immediately on this are the massive beds of the upper Rewah sandstone, a good 400 feet. At the foot of two or three other water-falls similar sections of the junction are observable.

At their eastern end the lower Rewahs have a thickness of about 500 feet, but if we follow them along the Kymore hills, they are found gradually to decrease, and finally to die out altogether. Thus, south-west of Rewah they are reduced to 400, at Badanpur to probably not more than 100, and not a trace of them remains north-west of Kuttungee, where lower Vindhyans and upper Rewahs are in contact. The possibility of this not being a *final* overlap and the shales of Jamghur and Mehalpur representing the lower Rewahs has already been discussed. To the north we find—

	Near Sohagi ghát.	*At Ginga hill.*
	Ft.	Ft.
Jheeree shales	230	200
Lower Rewah sandstone	20	80
Punna shales, about	250	250
	500	530

Bundelkund.

As we proceed westwards from Bundelkund the same peculiarity is observable as in the Kymore hills. The whole sub-group, except perhaps the sandstone, gradually diminishes in thickness, until near Buxwaho the last traces of shale disappear, and the great Kymore and Rewah sandstones are in contact. This overlap is, however, not final, for as we shall presently see, they reappear in the Gwalior country. A very clear case of overlap of the Punna shales to the north is observable at Kissengurh. The town is built on the lower sandstone which terraces out about a quarter of a mile from the scarp. At Kissengurh there is about 20 feet of shale beneath, but to the east of the town, on account of less denudation, the sandstone stretches still further north, and is then found to rest directly on the Kymores. Further east at Babupur, near Adjigurh Fort, another case occurs, where, in the main scarp, the lower Rewah sandstone is underlaid by the Punna shales, while to the north it reposes directly on the Kymore group. It is clear that the overlap is due to the Rewahs having been deposited on

a *sloping* floor of Kymores, which slope again, (a natural one, not due to elevation or disturbance), owed its origin to the pre-existing bank of crystallines to the north, which, no doubt, formed the limit of deposition.*

The following section illustrates the appearance of the Punna shales at Kissengurh near their extinction.

Kymore sandstone in thick beds—	Ft.	In.
Green shale	0	6
Coarse sandstone	0	2
Green shale	2	0
Sandstone	0	1½
Green shale	0	4
Sandstone	0	2
Fine silicious sandstone parted by shales	1	0
Red shale	0	6
Fine silicious sandstone and red shale	1	0
Green and red shales	2	0
Fine sandstone	1	0
Green and red shales	1	0

and so on, fine silicious irregularly flaggy sandstones alternating with equal quantities of red shale, the whole not exceeding 20 feet.

It is in the Punna shales that the diamond beds occur. There was, however, little opportunity of investigating them owing to their examination having been necessarily taken up early in the season, when the pits are not open, the country not being sufficiently drained to admit of their being worked. In one instance only was the bed seen in place; this was at Kumerea, south of Adjigurh, where it is a conglomeritic sandstone made up of pebbles ⅛ to ½ inch diameter, imbedded in a rather fine matrix which also includes clay galls. The lower Rewah sandstone here stretches out a considerable distance in front of the scarp, and the pit was just on the northern edge of this terrace, some 20 feet below the summit, and itself about 10 feet deep. On the top of the diamond bed

* Mem. Geol. Surv., India, Vol. II, p. 57.

was a foot or so of hard thin flaggy sandstone, and about seven feet of the same mixed with shale. A little further to the south and west on this terrace was an old pit between 30 and 40 feet deep, but the bottom filled with water, so that the rocks immediately above the diamond bed could not be seen, but there were certainly 10 to 15 feet of shale between it and the lower Rewah sandstone. In all the pits examined there must have been 10 to 20 feet of shale intermediate. The Punnas are here very thin, so that this position is not much above the top of the Kymores. There are some small outlying hills to the north at the village of Bungla and north of Babupur. The former is about 50 feet high, with Kymores at the base, then 15 to 20 feet of shale, capped in turn by the lower Rewah sandstone: this was the only outlying hill in which the shales were seen (on account of the northern overlap). A few hundred yards to the north-east, another little hill has been excavated in every direction by the old diamond searchers. Again at Babupur are numerous old pits and some sufficiently well preserved to admit of examination. They are about 15 feet deep exposing sandstone with thin flaggy beds at top, but no shales.

A bed of fine brown sandstone, including fragments of a green silicious rock and bits of red and green shale, was traced from Bumbhea to near Kissengurh, which is not impossibly the continuation of the diamond bed; that the natives do not work to the east is no proof that the beds do not continue in that direction. This is evident from the fact of there being no pits at Bungla, notwithstanding the hills all round, even to the north, having been extensively worked. It is therefore almost certain that at Bungla the diamond bed exists, yet is untouched.*

The lower Rewah sandstone is in places nearly 100 feet thick, in massive beds of 3 and 4 feet, fine textured, white and pinkish in color.

* See also Vol. II, p. 65.

Although both the Rewah shales are extinct from Kanoura to beyond the Betwa, it is not clear that the lower sandstone is so also. Where the shales are last seen, and where, consequently, the sandstone can be last distinguished, it retains its full thickness, and it also occurs in full force when first recognizable in the Gwalior dominions; so that the probability would seem to be that it exists in the interval also. There, however, the physical features of the ground, in the absence of lithological evidence, are not sufficiently strongly marked to allow of any separation of the different sandstones, and the question is further complicated by the overflowing trap.

Gwalior.

As we travel northwards from Chandairee this confusion lessens, and gradually the different sandstones stand out from each other, each marked by its own escarpment. At Ranod these are clearly delineated. The Rewah group generally, in the Gwalior district, resembles very closely, considering the distance between, the corresponding strata in Bundelkund. The junction between them and the Kymores is exceedingly sharp. Upon the massive beds of the latter are the thin earthy shales, as earthy at the base as elsewhere. They consist of alternations of red and green earthy beds, with layers of fine slightly earthy micaceous laminated sandstone, varying in thickness from 1 to 6 inches, mostly about 2.

They pass gradually into the sub-division above; the earthy beds become more and more silicious, until the rock graduates into a finely laminated thin-bedded micaceous sandstone. Above the strata are more massive, of rather loose and coarse white sandstone. The lower Rewah is mostly coarser, less hard and compact than the Kymore, generally white in color, and very often contains small ferruginous brown specks. The beds, although very thick, are seldom so massive or irregular. It occupies a more important position here than in Bundelkund or Rewah, sometimes attaining a thickness of over 300 feet.

The Jheeree shales are very similar lithologically to the Punna; red, green and yellow crumbling shales divided by thin layers of earthy sandstone. About 20 feet from the top there is a peculiar band of rather coarse, loose sandstone speckled brown by iron. It is very constant in the section between Nourabad and Busdree, a distance of 30 miles, but near the latter place it gradually dies out and is not again seen to the south. At Dudhai the shales become calcareous near the base, and further south there is some 30 or 40 feet of impure shaly limestone. North of the village this calcareous element is entirely wanting.

The thickness of the lower Rewahs south-west of Gwalior is thus about:—

Jheeree shales	150
Lower Rewah sandstone	280
Punna shales	160
	590

On north-west boundary.

We find the lower Rewahs again on the north-west boundary occupying the centre of the synclinals west of Kerowli, which were alluded to when describing the Kymores. The lower Rewah sandstone rises in both cases above the alluvium in a well-formed ridge, but the shales have been denuded away, and are seen only at the south-west end of the southern synclinal. The Punna shales do not require any special notice here. Only a small portion of them is exposed just under the town of Raontra. In the Jheeree shales which are seen at Amargurh, there is a band of limestone at base of the hill extending 20 or 30 feet up, but the lower part of it is obscured by alluvium. Above it there are between 200 and 300 feet of ordinary Jheeree shale, and over that again a considerable thickness of upper Rewah sandstone; the band of limestone, no doubt, corresponds to that mentioned at Dudhai.

Upper Rewah to the east.

The general character of the upper Rewah sandstone is very similar to the Kymore, but more false-bedding is apparent. The rock is generally a mixture of thick massive strata and false-bedded flags, usually hard and compact, and often glazed or semivitrified; yellowish- and greyish-white in color, sometimes reddish. Excellent sections are exposed in the cuttings at the Sohagi and Kuttra ghâts (see Plate 2), and still better where the Jubbulpur railway ascends the escarpment on to the second plateau. Its full thickness in the Rewah district where not denuded is nearly 500 feet, but the amount capping the edge of the escarpment is generally much less.

The strike and boundary, which run along the Kymore hills as far as that range is continuous, take a sudden turn south near Bilheri, until they meet the fault which brings up the slate series. West of this, in the Nerbudda valley, some of the most intricate geology of the Vindhyan area is found, which, as the Rewahs play a most important part in it, it will be best to describe here.

Nerbudda Valley.

The strata at Bilheri and north of it dip at a small angle toward the Bundairs, but about two miles south-east of the town we come upon a low ridge where the inclination is 50° to north-20°-west. If we follow this ridge out westwards, it is found to increase in altitude, until near Kuttungi it is not less than 600 feet high, precipitous and serrated in outline. At the same time there is a steady increase in the dip, which becomes nearly and quite vertical west of Buhoribun. The valley of Sohar is occupied by alluvium, on the south side of which, between it and the slate rocks, there is another range of hills also made of Rewah sandstone. The bedding is very obscure, but dips to the south as evidenced by the mode of occurrence in one place of Lower Vindhyans beneath it. Thus the

Mallet, Vindhyan Series. GE(

From sketch by T. Oldham

Second scarp sou

northern* and southern ridges are the remnants of a great anticlinal, the arch of which has been removed by denudation, and the space between them is occupied by Lower Vindhyans; which are, however, but rarely seen above the alluvium.

North of Singrampur the Rewahs come to the surface again in the form of a low dome, which is surrounded in succession by the various sub-divisions of the lower Bundairs. The harder of these, the limestone and lower Bundair sandstone, form a circle of hills with steep scarp-like slopes inside and a moderate inclination towards the exterior. A local fault brings the Rewahs and Bundair limestone almost in contact on the north.

The boundary between the Rewahs and Bundairs east of Kuttungi appears to be a faulted one. The latter are not seen close to the ridge, the vicinity of which is occupied by alluvium, but where the same junction is exposed further south-west, it is an undoubted fault. Another argument may be derived from the physical features of the country. It is a well known fact that where hard and soft strata alternate with each other, where denudation has acted extensively, the hard beds when thrown up at an angle tend to form hills, and this tendency *increases with increased inclination*. The circle of hills north of Singrampur is a remarkably good example of this. Here the Bundair limestone and lower sandstone are included between the upper and lower shales, and although only thrown up at angles of 10 or 15 degrees they form an almost unbroken circle of hills along their outcrop. Now, if the boundary east of Kuttungi be supposed to be a natural one, the lower Bundairs must be inclined at nearly the same angle as the Rewah sandstone, or from 60 to 90 degrees. In this case, one peculiarly favourable to the harder

* The northern ridge is known to the people of the district as the "Kymore," but as it is formed of *Rewah* sandstone, it might lead to confusion to adopt this name here. The southern ridge also is called "Keinjua," a range which in the Sone valley is composed of lower Vindhyans.

beds forming hills, even setting aside the protection they would derive from the greater ridge of Rewahs, it is difficult to understand how not a single vestige of either limestone or sandstone should appear above the alluvium along 30 miles of boundary. Thus there is much evidence in favour of a fault and *none* against it, so that it is reasonable to assume the boundary along here to be one. There is, however, no trace of it in the Sone valley, and it probably dies out gradually, becoming extinct near Bilheri or thereabouts.

With regard to the south-eastern fault, that along the main boundary, there is evidence of its existence between Sleemanabad and Mujouli. The slate series and Rewahs are close to each other all along, but as we know that the lower Vindhyans exist in the valley to the north, their non-appearance between the two other formations indicates a faulted boundary. To the south-west, north of Nursingpur, *supposing the lower Vindhyans to be extinct here*, it is possible that the Rewahs might have been deposited on sub-horizontal strata of the slate series which had previously undergone denudation, and both subsequently been brought to their present vertical position by the same movements. But though at first sight this theory seems to simplify the case by dispensing with one fault, it appears to render the production of the other still more difficult, and the probability is strongly in favor of the boundary in question being a faulted one. There is no trace of it, however, beyond Omarpani. The infra-Vindhyan rocks are completely obscured to the west by alluvium, and where they make their next appearance in the Dhar Forest, the Vindhyans are found in superposition.

The southern side of the Sohar (Bilheri) anticlinal is probably cut off obliquely by the south-eastern fault near Kuttungi, as in the Hirun river there, the slate series is found within a short distance of the northern ridge. The latter can be traced at intervals a long way to the south-west. The double fault may be well studied north of Nursingpur. Commenc-

ing at the Hirun river, limestone of the slate series is seen touching the Rewah sandstone. A little further west a band of hornstone intervenes; further on again north of Amoda, the lower part of the Bundair sandstone, with some shale beneath it, is thrown up vertically, while the beds *in* the scarp to north dip at a low angle. Hornstone of the slate series comes in next these rocks and then limestone, *the Rewahs being completely cut out.* Further west they come in again in direct contact with the nearly horizontal upper Bundairs; and so the section varies, there being, however, apparently but one place where the Rewahs are absent.

Muria hill is a remarkable peak due north of Nursingpur which quite overlooks the Bundair table-land, and one in which the strata are inclined at 60° to the south, being *inverted.* The hill itself has a steep slope on this side and is partially overhanging on the north, the underslope being made up of talus. The height and peculiar form of this eminence render it a conspicuous object for miles round.

In tracing the northern fault westwards, it is found gradually to diminish in depth or amount of throw. Thus, due north of Nursingpur, we have the upper Rewahs in contact with the upper Bundair, but a little to the west they are found next the Sirboo shales. Again north of the hill near Omarpani, which is the continuation of the Rewah ridge, we have the Gunoorgurh shales, and east of Buréli we find the Rewah sandstone both in the hill at Sateri and in the range to the north. Sateri is the last point where the Kuttungi ridge appears above the alluvium, and the last where there is any evidence of the northern fault, the throw of the latter being here much less than at Nursingpur; the entire traceable length of this fault from Bilheri to Sateri is about 130 miles.

During the investigation by the survey of the coal-bearing formations south of the Nerbudda, a cursory examination of the Vindhyan boundary north of the river led to somewhat erroneous opinions as to its nature.

The fault lines of the Nursingpur region were discerned, and from the rectilinear direction of the boundary along the whole course of the Vindhyan range, and the fact of no Vindhyan rocks having been found south of their present main boundary, while at the same time no littoral deposits were apparent indicating the original limit of the basin of deposition, it was conjectured that the southern fault was a constant feature along the foot of the Vindhyan escarpment. As explained above, however, there is no evidence of the existence of either fault west of Sateri. The island of vertical sandstone at Pullassi in the Dhar Forest, which was supposed to represent the Kuttungi ridge, is certainly a mere local contortion and unconnected with that ridge in any way. There is a great fault cutting off the Rewahs north-east of Burwai, but neither can this be supposed to be connected with the Kuttungi one, as the down-throw is in the opposite direction. To the east again in the Sone valley there is no evidence of the continuation of the fault line. The southern boundaries of both upper and lower Vindhyans are clearly natural, and along the course of the latter we have a markedly littoral deposit in the lower Vindhyan conglomerate.

East of Buhoribun and in the Rewah country, the Rewah sandstone is generally easily distinguished from the Bundair by its lithology alone, but the difference gradually diminishes westwards, so that at Hoshungabad there is little or none. By the Hirun river it is still strongly marked enough, the upper Bundairs being almost entirely fine-grained, red, very commonly speckled white. The great mass of the Rewahs is coarse greyish-white, although a few fine-grained beds occur like the unspeckled portions of the Bundair.

The range west from Diôri is physically the continuation of the Bundair table-land north of Nursingpur, although composed of a different geological group. It is made up of several irregular ranges, one behind another, all with a scarped face to the south and a reverse

slope equalling the inclination of the strata or about 15°. One is led to fancy from the contour that the valleys have been determined by shaly or softer bands, but on examination this generally proves not to be the case; two ranges frequently unite into one, so that their number varies in different places. North-east of Bari, they are frequently formed of a number of separate hills with a more or less deep gap between, but from Amraud to Hoshungabad the southern face is unbroken.

Where the Rewahs are covered by trap north of Diôri the beds on which the latter reposes appear somewhat altered by it, but not very markedly so. They are dark-red, fine-grained, vitreous. In the lower part of the scarp similar beds, but less glazed, are mixed with coarse grayish ones, and the lowest seen in the gorge west of Dioree, as well as at Sateri, are very coarse and massive. Some are highly conglomeritic, with pebbles up to 8 inches diameter, which are mostly quartzite, with a few of red jasper and impure hæmatite. The occurrence of such conglomerate beds amongst the lowest seen lends color to the idea of the Kymore being represented, as well as the Rewahs, amongst the sandstones of the Nerbudda valley. In the Hoshungabad region the sandstone is mostly dark red and greyish white, extremely fine grained to rather coarse, and sometimes containing pebble bands; rather thick-bedded as a whole but flaggy beds are frequent. Such are often produced by oblique lamination. The beds, particularly when massive, have a lenticular tendency. Mica is sometimes met with between the layers.

The thickness of the Upper Rewahs (possibly including the Kymores), as previously explained, increases enormously from east to west along their southern boundary. In the Rewah country it is somewhere about 500 feet, but not less than 1,000 at Kuttungi. A measurement at Jamghur, in which neither the highest nor the lowest beds were included, gave 1,700, while a rough calculation at Hoshungabad indicated

a thickness of close on 6,000. In the Dhar Forest, their most westerly limit in the Nerbudda Valley, they are supposed not to fall short of 10,000 or nearly two miles. A fine section of this immense accumulation may be studied along the course of the river, which winds through a rocky channel, often bounded by precipitous sides, where the disturbances which have affected the Vindhyans are clearly exhibited. Those disturbances are often violent, shifting the rocks and twisting them up vertically, but, as a whole, the strata of the Dhar forest area form a shallow synclinal, those in the eastern part having a general westerly inclination and *vice versâ*. The highest beds therefore are met with in the centre, and these bear a sufficiently strong resemblance to the lower Bundairs to render it not impossible that they should be referred to that group. If such be really the case, since they are found close to the fault, which brings the Vindhyans against the Bijawurs north-west of Burwai, it shows what an enormous throw that fault must have; equal to the entire thickness of the Rewahs.

Perhaps not unconnected with the disturbed state of the rocks in this region is the fact of its being the only one yet known where the Vindhyans have undergone the intrusion of igneous matter. Two or three trap dykes are observable in the bed of the Nerbudda, and a very large one occurs near the centre of the area, the course of which is marked by an elevated ridge. No doubt a closer examination would detect many more.

The Rewahs are more altered in the Dhar forest than anywhere to the east, the sandstone being so much vitrified as to pass frequently almost or entirely into quartzite. Thick shaly bands sometimes occur,* mostly quartzitic or silicious but sometimes more or less earthy, and the

* One of such being those beds at Pullassi formerly supposed to represent the Sub-Kymore, or lower Vindhyan series (Vol. II, p. 189); as previously stated, however, that series is absent in the Dhar forest, not extending further west than Kuttungi.

bedding generally is not so thick or massive as to the east. In places, as between Dhari and Rampura (north-west of Punassa), some portions are conglomeritic, even passing into conglomerate. The pebbles are mostly under an inch diameter, composed chiefly of variously colored quartzite and red jasper. The matrix is often dark purple, and the rock then bears a strong resemblance to some varieties of the "hornstone breccias" of the Bijawur series. Indeed it is very doubtful to which series certain rocks of this class should be referred. Some beds of the Rewahs have evidently been made up almost wholly of debris from the Bijawur hornstones, and as they (the Rewahs) have been considerably indurated, they naturally bear a close lithological resemblance to the older rocks. South of the Nerbudda, in the neighbourhood of Chandgurh, such difficulties frequently occur. One case was observed where a red breccia between the Bijawurs and Vindhyans contained large pieces of a rock similar to itself. Here there could be little doubt that the rock was Rewah and the fragments Bijawur, but other cases are not so clear.

Bundelkund.

Regarding the upper Rewahs in Bundelkund there is little calling for remark. Their lithology is identical here and to the east where they have been already described, and their thickness seems very uniform. Like all the other members of the series there, they dip gently towards the south, a result of original deposition, not of subsequent elevation, and throughout, the inclination of the strata seems to coincide exactly with that of the glacis which stretches from the edge of the Rewah escarpment to the boundary with the Gunoorgurh shales, a fact of very general application amongst the Vindhyan sandstone slopes. East of Ságar the strike of all the sub-divisions takes a sudden turn to the south, and the Rewahs continue past Soorkhi. There can be little doubt that they underlie the trap between that place and the Nerbudda valley—the whole Bundair group

being removed or wanting. The various members of the formation, those at least which do not become extinct, thus outcrop in a series of concentric ovals, the central one being occupied by the upper Bundairs between Nursingpur and Nagode.

Gwalior.

In the Gwalior country the upper Rewahs do not exceed 150 feet in thickness, strongly contrasting in this particular with the immense development in the Nerbudda valley.

South-west of Agra.

Their next appearance is west of Agra. The celebrated remains at Futtipur-Sikri are built on a ridge of upper Bundairs dipping south-east at 30°, about ten miles north of which is a second ridge where the beds dip at 20°. The latter is isolated in the alluvium, which obscures all the rocks between the two ridges, but the lithological characters of the strata in the northern one, combined with their inclination and position, can leave little doubt of their belonging to the Rewahs. The same ridge is continued at Rudawul, where it is much closer to the Bundair, and where the strata in both dip at very high angles, and is again found about half way between Byana and Hindoun; but here the dip is much lower. The upper Rewah sandstone also forms the centre of the synclinal to the south-west of Kerowli.

The mode of extension of the upper Rewahs to the west is as yet uncertain, but they have been met with at Indergurh, and clearly seem to be represented in the Neemuch country.

(c.)—Bundair Group.

Lower Bundairs.

The Bundair group from being the highest member of the series covers probably a larger superficies than any of the others. Of the region known up to the present time, they occupy a very large tract from Ságar to beyond Rewah;

they are again met with at Hoshungabad and are very probably represented in the Dhar forest, besides in the extreme north spreading over a large extent of country to the south-west of Agra. It seems also that they cover a large portion of that little known region extending from Siprí westwards to Neemuch, as in a traverse made across it they were passed over almost continuously from Boondee by Kotah to Chuppra where the trap makes its appearance. It is further shown by inliers far away from the main area that a considerable portion of the trappean area, north of the Nerbudda and east of Neemuch, is underlaid by strata of the Bundair group.

To the east.

Commencing the description of the lower Bundairs at their eastern development we may trace their lowest beds at the fall of the Tonse. Resting on the thick and massive beds of the Rewahs are about three feet of a thin-bedded kind of sandstone, which passes above into a greenish-grey sandy shale, the two being mixed with each other in the transition. This shale quickly loses the arenaceous element and passes into "thin shales. The perfect horizontality of the bedding is remarkable, and the thinnest layers are continuous all through for 300 yards; the lower eight feet are alternating gray, greenish, and yellow sandy shales, wrinkled and minutely laminated, all slightly micaceous; some show ripple-marks, and in some the irregular cross markings of clay might be taken for vegetable impressions and casts; in the upper seven feet there are partings of flagstones."* The beds above these become gradually calcareous, and higher up the Gunoorgurhs are a mixture of red earthy shale and thin impure beds of limestone. In the Beehur, east of Kudda, the beds, which are probably not much above those at the Tonse falls, consist almost wholly of red shale with a few calcareous bands. Higher up in the section the latter are frequent, varying from tolerably pure limestone to marl and calcareous sandstone; thus one mile south-east of Dokeri

* Mem. Geol. Surv., India, Vol. II. p. 54.

in a cutting to drain the tank there, about twenty feet of red clunchy shale is exposed, which in part is greenish-white, and contains one 18 inch and two or three smaller bands of marl. Again south-east of Oomree in the Mohunna stream we meet heavy red shale with minute calcareous strings, which are chiefly in the planes of bedding, but many penetrate the rock in other directions. Some beds pass into a kind of impure, earthy, red and white limestone, which, in common with the shale, generally has a glistening sub-crystalline appearance, and is often marked by rippling. The following section in the Bichia stream, about a mile south of Burrigaon, is a very characteristic one of the Gunoorgurhs somewhat higher up in the series.

		Ft.	In.
(*a*).	Very brittle dark red shale ... ... seen ...	1	0
(*b*).	Light yellowish-grey marl	0	6
(*c*).	Red shale like (*a*)	0	6
(*d*).	Marl like (*b*)	0	4
(*e*).	Ditto rather shaly and reddish	0	8
(*f*).	Yellowish-grey ditto with a little reddish	2	8
(*g*).	Red shale like (*a*)	1	4
(*h*).	Tolerably pure limestone	0	1
(*i*).	Red shale like (*a*)	0	3
(*j*).	Hard pinkish-grey limestone	0	2
(*k*).	Red shale like (*a*)	1	6
(*l*).	Marl like (*b*)	0	1
(*m*).	Red shale; more calcareous, with some marl and two or three half-inch bands of limestone...	2	6
	TOTAL	11	7

A mile or so west of this we find, in a small isolated hillock, alternate beds of red shale and marly light-yellowish limestone, some of which are slightly contorted and brecciated on a small scale; fragments of red shale being re-cemented by the calcareous element which contains small cavities lined with calcite.

The red shale which is, generally speaking, undisturbed and horizontal, gradually becomes more and more calcareous until it passes

into the Bundair limestone. The transition may be studied in the small outlying hills near Goorha, where, above the red and green shales and marly beds, are 50 feet of limestone, of which the layers near the bottom are impure and shaly, but near the top thick-bedded (2-4 feet) moderately pure and some very hard; the prevailing tints are grey, pink and yellowish, and here, as elsewhere in the Rewah district, the rock contains thin bands and flattened nodules of black chert. The passage is also observable in the Serangi stream just west of Oméri,

	Ft.	In.
Dark red earthy shale with a few calcareous laminæ	3	0
Yellowish-white calcareous shale with bands of impure limestone	5	6
Bed of arenaceous limestone with nodules of black chert ...	1	0
Thin-bedded impure shaly limestone	5	0

above which the massive blue limestone comes in.

The section above the limestone (Sirboo shales, &c.,) may be taken up in the Gusri stream, where the beds are seen at intervals. Rather more than a mile from the mouth, the Bundair limestone occurs of the usual aspect, except that it is rather thinner-bedded than usual, dipping west-20°-north at 5°. One hundred and fifty yards up stream are a few feet of silicious green shale in beds of one or two inches thick; then a few feet more of blue compact limestone. One hundred yards beyond this are greenish, earthy, slightly micaceous brittle shales passing above into red shales, containing, higher up, thin bands of more or less calcareous rippled sandstone. Beyond this the shale changes again to green with many bands of sandstone and impure limestone, and about 200 yards east of the Deccan road a 10 feet band of limestone comes in; in the rising ground to the east of Myhere some feet of sandstone occur, which represent lower Bundair sandstone, here reduced to a very small thickness. The amount of shale between it and the limestone is greater here than usual, as it generally does not exceed 20 or 30 feet, and hence has not been invested with any special name.

The Sirboo shales which rest directly on the lower sandstone are well exposed on the flanks of Sirboo hill. The following section was taken at the south-west angle:—

	Ft.	In.
Gently inclined ground at base of hill, shales not seen ...	80	0
Thin, regularly-bedded, greenish, aluminous shale, brittle and splintery	26	0
Similar shale with bands of sandstone from $\frac{1}{4}$ to 1 inch thick ...	26	0
Greenish, aluminous shale, thicker bedded, some few beds as much as 4 or 5 inches: grey in some parts: much broken up where exposed: a few sandy layers	44	0
Greenish hard silicious flags more or less broken	60	0
Alternate silicious and aluminous shale	17	0
Aluminous shale with arenaceous layers from $\frac{1}{8}$ to 4 and 6 inches	26	0
Similar shales without arenaceous layers, some beds greyish ...	320	0
Obscured by talus; seems nearly all shale	165	0
Sirboo shales (a few beds at bottom not included)	764	0
Upper Bundair sandstone, to top of hill	137	0
	901	0

The outlying hill at Ponri (450 feet high,) south of Myhere, exposes similar thin-bedded aluminous shale, slightly micaceous with occasional bands of sandstone $\frac{1}{4}$ to 4 inches thick; chiefly greenish with some dark grey bands. The general aspect of these beds is everywhere very much the same wherever they are seen; in the Bundair scarp (see Plate 3) or in the outlying hills to east. When unprotected by sandstone talus, as on the hill at Ponri, they weather into very steep precipitous faces.

At Sirboo hill the thickness of the Sirboo shales is about 750 feet, but this amount is somewhat reduced at Myhere, where the lower Bundairs altogether have a thickness of about 1,200 feet. In following them up the Tonse valley the lower members seem to diminish somewhat, but expand again to the westward.

BUNDAIR SCARP, FROM JUBBULPUR ROAD WEST OF MYHERE

Showing Sirbu shales and upper Bundair sandstones (pl. 4)

Photozincographed at the Surveyor General's Office Calcutta.

Nerbudda Valley.

From Bilheri to within some miles of Kuttungi, they are, to all appearance, completely cut out by the northern fault, but re-appear in the Singrampur valley. Here remarkably good sections present themselves, and the whole of the upper Vindhyans existent here may be studied within a space of two or three miles.

In a little hill, one mile west of Sagoni, and resting directly on the massive Rewah sandstone, with a perfectly sharp division, the Gunoorgurh shales are found. In color they are deep Indian-red, earthy, micaceous, in beds mostly ½ to 2, often 4 or 5 inches thick, and include a few thin somewhat arenaceous layers of a greenish-grey color. They are generally brittle, so that it is not easy to obtain a good specimen of them, and are not calcareous in this region, until at about 200 feet from their base they gradually become mixed with thin bands of impure limestone, and higher up with a few of red, earthy sandstone. The limestone comes in above. Many parts of it are shaly, others thicker-bedded and purer. Near Sagoni the strata in the middle portion average about 18 inches, dark grey in color, weathering light or yellowish-grey. The lower and upper portions are thinner-bedded and inclined to shaliness; here and there arenaceous bands making their appearance. Between the limestone and the sandstone above there is a very constant band, about 20 feet thick, of greenish-grey shale containing layers of impure limestone and sandstone, the former chiefly in the lower part and *vice versâ*. The lower Bundair sandstone is rather thin-bedded; some parts pitted with numerous red clay galls, others hard and fine-grained without any such. Red and sometimes dirty-white are the prevailing colors, and the rock is much rippled. Its somewhat coarse texture and the abundance of clay galls, as well as difference in color, &c., distinguish it from the upper Bundairs.

In the vicinity of Singhorgurh a few feet of greenish-grey shale rest immediately on the sandstone with a well-marked division, and then

a thin band of impure red and greyish limestone which is not observable elsewhere. Above this we find the ordinary greenish-grey, aluminous, slightly micaceous silty shales which form the great mass of the Sirboos. They are so brittle that it is impossible to obtain a hand specimen; in places they become red, and thin layers of earthy sandstone are not uncommon. The above characters are very constant and may be observed through several hundred feet, till near the top they gradually lose their aluminous character and become more and more arenaceous till they pass into the upper sandstone. The thickness of these strata in the Singrampur valley is about as follows :—

	Feet.
Gunoorgurh shales	250
Bundair limestone	200
Lower Bundair sandstone	200
Sirboo shales	800
Lower Bundairs	1,450
Upper Bundairs	650
Bundairs	2,100

From Kuttungi to some miles beyond the meeting of the Hiran and Nerbudda rivers, the lower Bundairs are sunk out of sight by the northern fault, save in one or two places where the highest beds imme-

Fig. 9. Section of Bundair scarp and adjacent hills near mouth of Hiran river. *a*, Slate series : *b*, Sirboo shales : *c*, Upper Bundairs.

diately below the upper sandstone are visible, and where they are, in consequence of that fault, thrown up into a nearly vertical position (Fig. 9).

To the north of Nursingpur, where the Bundair escarpment turns northwards to meet the trap, the Sirboo shales are found again, several

hundred feet thick, and at Rampur the Gunoorgurh shales appear underneath the sub-trappean limestone. A closer search along the foot of the trappean scarp between the above two localities would perhaps discover an outcrop of the Bundair limestone.

Westwards from Rampur no lower Bundairs occur within the limit yet surveyed for more than 80 miles, their next re-appearance being near Hoshungabad. Here they are greatly reduced in thickness, and seem to include only the two lowest of the four sub-divisions described to the eastward. The section comprises—

Red shales	30	feet		
Bundair limestone	110	„		
Gunoorgurh shales	390	„ ...	*(d)*—Red shales	... 125 feet.
			(c)—Red limestone	... 15 „
			(b)—Red shales	... 130 „
			(a)—Greenish shales	... 120 „
Lower Bundairs	530	feet		

The highest part of the Rewah sandstone is rather thin-bedded, and becomes more so till it gradually passes into arenaceous shale, the junction thus differing from that in the Singrampur valley. The section up the south end of Gunoorgurh hill includes, at the base *(a)* greenish-grey or greenish silicious, argillaceous, slightly micaceous thin-bedded shales mixed with arenaceous layers and rippled. These higher up are interstratified with and pass into dark red argillaceous shales *(b)* similar to those at Sagoni. They are mostly pure argillaceous, brittle and splintery, but where calcareous are less frangible. Above these comes in a band of dark red limestone *(c)* and thin red shales again *(d)*, then with a tolerably well marked junction comes thin and evenly bedded silicious looking limestone, of which the usual color is light grey, sometimes greenish-grey or pink. It is divided into angular pieces by sharp vertical joints, and bears considerable resemblance to the Rotasgurh

limestone. The shaly band above the limestone is similar to the beds below.

The Rewahs of the Dhar forest, as previously explained, form a shallow synclinal, the highest beds therefore being in the centre or trough; these consist of red and green earthy, slightly micaceous and calcareous shales capped by sandstone, which bear a considerable though not a strong resemblance to the Gunoorgurh shales more to the eastward. It is possible that they do represent the lower Bundairs, but doubtful; the lithological characters of the lower Bundairs vary so little between the Rewah country and Hoshungabad, a space of nearly 300 miles, that it seems improbable they would alter so much between Hoshungabad and the Dhar forest. Hence, as the point is doubtful, these beds have on the map not been separated from the Rewahs.

Bundelkund.

In following the lower Bundairs westward from Rewah, a good section may be found 20 miles north-west of that town in the hill at Kotar, where there is 225 feet of limestone, the bottom beds not included. Resting on this rock with a sharp division are some yellowish-grey aluminous shales which, higher up, become red. West of the Tonse (as also to the east, but to a less extent) arenaceous bands are very frequent in the limestone, and subordinate bands of limestone also occur above the main run. Rippling is often observable in the impurer parts. The black chert, which is so common about Rewah in the form of thin seams and flattened nodules parallel with the bedding, is very rarely met with west of Nagode. Owing to its comparative hardness, the limestone determines a slight elevation of the ground along its outcrop which influences the drainage of the valley between the Rewah and Bundair scarps.

The lower Bundair sandstone, which is very thin to the east, first begins to form a conspicuous member of the series to the west of the Kane. Thus, between Hutta and Nursingurh, it forms at intervals a low

escarpment along the southern bank of the river, and is not less than 50 feet thick; and owing to the very slight inclination of the beds along this valley, its outcrop is often two or three miles wide. Between it and the limestone there is sometimes, but not always, a band of greenish-grey and red shale. The general character of this sandstone is thin-bedded and rather coarse-grained, with numberless little flat cavities parallel to the bedding, from which clay galls have weathered out, or in which occasionally the segregated matter is present.

The Sirboo shales do not call for any special remark in this region, being exactly the same here as further to the east. Their junction with the upper sandstone as seen near Summuna, three miles east of Dumoh, is sharper than usual, the greenish-grey shales being covered by thin-bedded dark red sandstone.

To the west of Dumoh the outcrop of the lower Bundairs takes a southerly turn, and the various sub-divisions may be traced as far as Rehli, where they disappear beneath the trap. It is clear that their outcrop is continuous underneath that formation between Rehli and the Nerbudda valley, and we find them re-appear north of that river as described above (p. 85).

Gwalior.

In the interval between the last mentioned localities and the country to the west of Gwalior, the Bundairs are as yet unworked. On comparing them in the latter region with the same rocks as known in Bundelkund, several points of difference present themselves, some of which are of sufficient importance to render it not improbable that further research to the westward may necessitate more or less modification in the classification at present adopted.

From the north-westerly inclination of the Vindhyans generally, thereabouts, the whole of the lower Bundairs may be crossed between Bijapur and Mandrael, although stretches of alluvium prevent one's obtaining an uninterrupted section.

In the Bansri nuddee, near Babaricha, resting on the massive beds of the Rewah sandstone, and with a gentle north-westerly dip, we find—

	Ft.	In.
Green calcareous shales	3	0
Fine ripple-marked sandstone	1	0
Calcareous shales with strings of calcite	1	6
" sandstone	0	8
Fine thin beds of sandstone with shaly partings ...	6	0

and then a few feet of cream-colored earthy limestone in beds mostly from 2 to 3 feet thick.

From this point north to Jhilalgurh, at the foot of the next range of hills, a distance of about four miles, the rocks are obscured by alluvium. The Jhilalgurh range presents a bold escarpment on the south, east and north, and slopes gradually down on the north-west to the level of the plain. The section on the south side is nearly the same as on the north five miles distant, which shows how very nearly horizontal the strata are hereabout, a point of some importance as will be seen presently. At Jhilalgurh we have, in ascending the scarp—

	Ft.
Limestone	240
Green calcareous shales	40
Limestone	50
Shales and sandstone	130
	460

The junction between the shale and sandstone (a white and loose grained rock with pebbles of quartz) is covered by debris. The section in the outlier at Kaodoli, six miles north of Jhilalgurh, comprises

	Ft.
Green calcareous shales	30
Limestone	50
Sandstone	20
Red and purple shales	10
Sandstone	40
	150

From this hill north to the Chumbul, a distance of eight miles, nothing but the alluvium is seen.

On the right bank of the Chumbul a small patch of fine white sandstone is exposed, and on the other bank the Bundair limestone is seen, obviously higher in the section than this white sandstone.

Whether the Bundair limestone seen in the Chumbul and under the Dholpur scarp is the same limestone as that of the Jhilalgurh hills, is a matter of some doubt. From the above section one would be inclined to consider them the same. The sandstone and shales above the limestone at Jhilalgurh are very similar to those above the Bundair limestone at Sewar; resting on the limestone in both places is sandstone, then a few feet of red and purple shales and then a loose sandstone with pebbles of quartz. We have seen how flat the rocks are in the Jhilalgurh hills, and on the north side there are even some southerly dips, so that judging from this section alone one would probably conclude that the limestones are identical.

An examination of the same strata near Siprí, however, where a more complete and continuous section is obtainable, throws much doubt on this identification, and indeed renders it more than probable that the two limestones are distinct. In passing west from Siprí, after crossing the upper Rewahs, one obtains a fine section of the Gunoorgurh shales up to the Jhilalgurh limestone. The Jhilalgurh scarp is here nearly 600 feet high, the limestone of the lower part being capped by a considerable thickness of sandstone. The latter dips from the edge of the escarpment at an angle of about 3° to the north-west, and is exposed continuously to within four or five miles of the Chumbul. On the right bank of the river a very similar sandstone presents itself covering which on the left bank the Bundair limestone is seen. The interval between the Jhilalgurh sandstone and that seen in the Chumbul is occupied by alluvium, and it is here that the only uncertainty in the section arises. There may be a reverse (south-east) dip between these two points which would account for a repetition in the

section of the same limestone, but such does not seem probable. Although the section immediately above the Bundair limestone at Sewar agrees pretty well with that above the Jhilalgurh limestone at Jhilalgurh, this agreement is not found in the more extensive (thicker) section west of Siprí. There, the strata above the two limestones are not the same; the question requires further investigation, but judging from the knowledge at present possessed, the probability seems to be that the limestones are different. If this be the case, instead of the Gunoorgurh shales alone we have here beneath the Bundair limestone—

1st. Shales.
2nd. Limestone.
3rd. Shales and sandstone.

The Bundair limestone in this region is very peculiar. It is a dirty impure looking rock; light-blue, brownish or yellow in color, in places largely crystalline and often containing strings and veins of calcite; the lower beds sometimes include bands and nodules of chert. A peculiar concretionary (?) structure is largely developed, which even gives the rock the appearance of a limestone conglomerate.

The remaining portion of the lower Bundairs, that is, from the limestone to the base of the upper Bundairs, corresponding to the Sirboo shales, consists of alternations of sandy shales and bands of sandstone. A complete section may be traced from Sewar on the Chumbul to Sonaka Gurja at the top of the escarpment.

Upper Bundair sandstone—

		Ft.
Sirboos	... Shales	95
	Sandstone	4
	Shales	16
	Sandstone and shales	150
	White sandstone with yellow spots ...	55
		320

Bundair limestone—

The thickness of limestone here is about 260 feet. The shales are finely laminated, not differing much in composition from the sandstones. They are slightly more earthy, which determines the difference in structure. These alternations of hard and soft bands produce a deviation from the ordinary outline of the escarpment. Instead of one cliff and under-cliff, the escarpment is broken up into a series of terraces, of which the upper are sometimes worn back a considerable distance from the lower; even as much as a mile and a half. The following examples are selected in illustration :—

At Sewar we have blue (Bundair) limestone at the bottom of the scarp and then

		Ft.
	Impure yellow earthy limestone	10
FIRST TERRACE ...	Fine white sandstone with numerous yellow specks	10
	Earthy red and yellow shales	70
SECOND TERRACE ...	Coarse white sandstone very similar to that of lowest terrace at Golary	

At Golary five miles to the west the continuation of the section is traceable—

		Ft.
SECOND TERRACE (?)	Coarse white sandstone, sometimes pinkish, with yellow and brown specks	20
	Shales	10
THIRD TERRACE ...	Pink sandstone with brown specks	20
	Sandy red shales	24
FOURTH TERRACE ...	Pink sandstone with white and brown specks ...	6
	Yellow and red shales	20
FIFTH TERRACE ...	Deep red sandstone with white specks ...	6
	Red and green silicious shales, spotted yellow ...	40
	Fine red sandstone, spotted white and pinkish; in thick beds, but finely laminated (upper Bundair)	150

To the west.

The lower Bundairs where exposed in the valley north-east of Kerowlee do not present any marked lithological differences from the same beds in the Dholpur scarp. Their stratigraphy, which is rather complicated, will be best described in

conjunction with that of the upper sub-group. They have not yet been traced continuously to the westwards, but appear to occupy a large tract of country between Siprí and Neemuch, the Bundair limestone having been found to occupy most of the ground as far as Chuppra in a traverse from Bundi to Guna.

Upper Bundair.

Bundelkund.

The 'upper Bundair' sandstone which constitutes the highest member of the series is the only one still to be described. The large spread of these strata in the jungly country between Myhere and the Nerbudda, forms a very shallow basin, along the northern and southern limits of which the strata dip inwards from the edges of the escarpment at an angle of 5° or 10°, while in the interior of the basin the beds, while gently undulating, are on the large scale horizontal. The faulted nature of some portions of the southern boundary does not affect this arrangement. The inward dip is less marked on the eastern and western edges of the basin, on account of the elongated form which the basin possesses.

A fine section illustrating the passage from the lower to the upper Bundairs may be observed in an indentation of the scarp north-west of Kuseru (near Myhere)—

	Ft.
Thin-bedded, brittle, slightly micaceous, concretionary, blackish grey shales, more or less silicious or earthy——seen	35
Yellowish-grey or greenish, thin, earthy and silicious shales, some parts very hard and flaggy, with some impure arenaceous layers	45
Alternate arenaceous and earthy, thicker, bedded-green and red shales ...	15
Impure, earthy, dark red sandstone with small lenticular layers of red and green shale	12

which passes above into the ordinary upper sandstone.

In mineral character this rock differs considerably from the Rewah and Kymore sandstones. The beds are generally thinner, varying from 6 to 18 inches, though many occur of 3 and 4 feet. It is fine-grained and comparatively soft, in consequence of which the Bundair scarp seldom

presents the bold precipices which relieve the outline of the lower escarpments. Bands of dark red shale are often interstratified, and the sandstone itself is often shaly through a large thickness. It is generally fine-grained, red, with small white spots (a very characteristic variety), greyish white and purplish red. In the fine white flags which are sometimes met with, dendritic markings are to be found. The neighbourhood of Dumoh furnishes fair specimens of these in the magnificent flags which are quarried there.

Ripple marking, which is common throughout the greater part of the Vindhyans, occurs in immense profusion and variety in the upper Bundairs. Sun-cracks and water channels are also not unfrequent, but rain drops have not been hitherto observed, a rather remarkable fact, considering how common they are in the lower Vindhyans and the abundance of sun-cracks in the strata we are speaking about.

The prevalence of rippling and such like marks shows how shallow the water must have been in which the Vindhyans were deposited. We have already seen that both in Bundelkund and the Sone valley there is reason to believe that the present limits of the formation are also nearly those of original deposition. Combining these observations with the fact, that several members of the series thin out partially or entirely from east to west, and with the increase in width of the area in the same direction, it seems a plausible supposition to regard the eastern development of the Vindhyans as the result of estuary deposition. In such case the sediment would have been supplied at the head of the estuary by some great river coming from the eastward, and which must have flowed over the crystalline rocks of Bengal, from the wasting of which we may suppose the eastern Vindhyans to have been in great part formed. In the course of time the estuary may have been completely choked up with sediment, and the mouth of the river have been advanced further west, so that the absence of the higher groups in the extreme east, may be due to their never having been deposited there, and not only to subsequent denudation.

As the Vindhyans in this eastern region are not less than 3,000 feet thick and are rippled throughout their entire thickness, it seems clear that the ground must have been gradually sinking during their formation, as otherwise either the water would have been at first far too deep for rippling, or else the newly formed strata would have risen to the surface, and further subaqueous deposition been put a stop to. Supposing then the estuary to have been of tolerably uniform depth, and an equable sinking throughout, after the deposition of the Kymores (which are 1,300 feet thick at Rotasgurh), while the depth of the water remained the same at the upper end of the estuary, by the deposition balancing the subsidence, there would be at least 1,300 feet over the Kymores at their most westerly limit, where they appear to die out. Under these circumstances, it is difficult to explain how the beds were rippled. It is highly improbable that while the ground near the mouth of the estuary remained stationary, the sinking increased from west to east, so as to balance the decrease of sediment in the opposite direction. If, however, the estuary be supposed to have had steep banks at the upper end, plunging at once into deep water, while lower down they gradually became more gently inclined as the estuary widened, then, if an equal depth of strata were deposited in the centre of the channel throughout, as the ground sank, the upper beds on the sloping bottom would gradually overlap those previously deposited, and the thickness near the shores would always be small. Thus, where the beds are now exposed in the scarp, they appear to thin out from east to west, and really do so along the coast line, but in the centre of the basin the thickness may be constant. The water, on this supposition, would be of nearly equal depth throughout, and the beds would be rippled throughout, both vertically and horizontally.*

Being covered by no other beds, the original thickness of the upper Bundairs cannot be determined. At Kuttungi there are 650 feet, and

* These remarks, although introduced in connexion with the subject of rippling, further favor the idea of the extension of the Kymores along the Nerbudda valley. See p. 54.

near Kotah in the northern escarpment 450, but further east the scarp is generally only capped by one or two hundred.

Hoshungabad.

The Vindhyans near Hoshungabad have been considerably altered, and there is here no lithological difference by which the Rewah and Bundair sandstones can be distinguished from each other, and their separation can only be effected by means of the lower Bundairs between. In the case of some outlying hills, as those south-east of Hoshungabad, one cannot tell with certainty which group the beds belong to. The thickness of the Bundair sandstone here is vastly greater than to the east, and has been estimated at 3,000 feet.

It is not perfectly certain that this rock may not be the *lower* sandstone. Near Kuttungi we have in ascending order—

	Feet.
Gunoorgurh shales	250
Bundair limestone	200
Shale	20
Sandstone	200

and at Hoshungabad—

	Feet.
Gunoorgurh shales	390
Bundair limestone	110
Shale	30
Sandstone	3,000

The sandstone at Hoshungabad rests on the limestone as the lower Bundair sandstone does at Kuttungi, and there is no reason why the lower sandstone should not expand from 200 to 3,000 feet, when the Rewah does so from 500 to 6,000; but, on the other hand, it may thin out westwards as it does eastwards. In the latter case the Sirboo shales must be extinct also. The Hoshungabad rock then *may* be, firstly, the lower sandstone greatly increased in thickness, in which case the examination of the country further north would probably reveal the higher members of the

group; secondly, it may include *both* sandstones, the Sirboo shales being extinct; or thirdly, it may be the *upper* sandstone, the Sirboo shales and lower sandstone being extinct.

It will be seen from the map that in one place to the north-west of Hoshungabad, the Bundair and Rewah sandstones are in contact. This is owing to a small fault. As the highest beds of the lower Bundairs are sometimes seen in contact with the Rewahs along the line of fault, the throw must be equal to the thickness of the former sub-group, or 500 feet.

Dhar Forest.

The shales in the centre of the Dhar forest are covered by a sandstone which caps a line of hills along the north bank of the Nerbudda. If the shales be lower Bundair (p. 88) then the sandstone is probably upper.

South-west of Agra.

The upper Bundairs are found again to the south-west of Agra. They cap the escarpment which runs westwards from Dholpur along the north bank of the Chumbul, but there only show a thickness of about 100 feet, a very small part of the entire development. The most compact section is from Jat-Araini east to the Kerowlee valley, where the lower Bundairs make their appearance. The Jat-Araini hill is about 200 feet high, of nearly horizontal sandstone, but from this point eastwards, the westerly dips gradually increase. At Araini the sandstone dips at 7°, at Madanpur at 10°. The section is three miles long, which, taking 5° as the average dip, would give a thickness of ... ... 1,440 feet

dip, would give a thickness of	1,440	feet
and height of Jat-Araini hill	200	,,
Total ...	1,640	feet

The Futtipur-Sikri ridge is in places nearly 500 yards wide, dipping at about 30° to south-east, which would indicate a thickness of 750 feet, in which neither upper nor lower beds are included.

The upper Bundairs consist entirely of sandstones of various colors, and varying in texture from very fine to a rock almost coarse enough to be called a conglomerate. The prevailing color is dark-red with white, or sometimes greenish, spots, or frequently the white is disposed in streaks parallel to the bedding, or in large irregular blotches. The lowest beds of the sandstone, as well as the top of the shales beneath, are mostly of the red variety, spotted with green. Above this there is nearly 100 feet of fine greyish sandstone and then the coarse sandstone or grit. About 60 feet higher up we find the more characteristic colors, *viz.*, the red, spotted white, and the red and white in patches. The latter appear to be more frequent in the upper beds of the group.

To the south-west of Kerowli the upper Bundairs, and further west the lower Bundairs, are brought against the quartzite series by a great fault. It is difficult to estimate the throw accurately, but it cannot be less than the thickness of the Vindhyans (excluding the highest beds of the upper Bundairs,) and that of the quartzites exposed, making a total of at least 4,000 feet. The throw appears to increase to the south-west, for at Indergurh the lower Bundairs are faulted against the *schist* series. Following the fault in the other direction to the north-east, we find it to gradually diminish until it at length dies out. Thus, in the valley north-

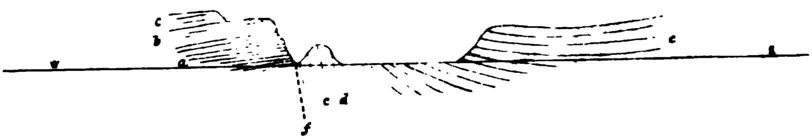


Fig. 10. Sketch section across Singanpur valley. *a*, Lower Bundair shales with beds of sandstone: *b*, Red upper Bundair sandstone: *c*, Grey sandstone: *d*, Coarse sandstone: *e*, Sandstone, highest beds of the series: *f*, Fault.

east of Kerowli the lower Bundairs are faulted against the upper. The sketch section, Fig. 10, represents the section near the head of the valley a little north of Singanpur where only the highest beds of shale make

their appearance. A little further on merely different beds of the upper Bundairs are brought in contact, and the fault gradually becomes no longer traceable.

The ridge at Futtipur-Sikri has been previously alluded to, in which the strata dip south-east at about 30°. It is continued south-westwards as far as Kerowli, but the inclination varies greatly, being vertical at Rood-awul, 5°—20° at Byana, and nearly vertical again south of Hindoun.

Little is known as yet respecting the upper Bundairs further to west, but they have not been found beyond the Bunass in any of the ground hitherto examined. Future work, however, over larger areas, may prove that they extend in that direction as far as the other members of the series.

CHAP. VII. THICKNESS: AREA: FOSSILS: AGE: DENUDATION.

Having thus described the Vindhyans in detail, it remains to discuss some points connected with them as a whole. As may have been surmised from the foregoing, the total thickness varies much in different parts of the area, partly from original conditions of deposition, and partly from the effects of subsequent denudation. In the extreme east towards Rotasgurh we have about as follows:—

Thickness of Vindhyans.

	Feet.
Lower Vindhyans	2,000
Kymores	1,300
	3,300

In the neighbourhood of Rewah, the full thickness of the upper Vindhyans is perhaps about 2,500 feet. At Kuttungee, where the lower series is extinct, the thickness of the upper is about thus—

	Feet.
Upper Rewahs	1,000
Lower Bundairs	1,450
Upper Bundairs	650
	3,100

From this point westwards the formation thickens rapidly, and at Hoshungabad the following may be taken as an approximation:—

	Feet.
Upper Rewahs	6,000
Lower Bundairs	500
Upper Bundairs	3,000
	9,500

while in the Dhar forest the full amount has been estimated at some 10,000 feet. In the Gwalior country, a section north-west from Sipri, would be about as follows:—

	Feet.
Upper Kymores	250
Lower Rewahs	450
Upper Rewahs	300
Lower Bundairs	1,500
Upper Bundairs	2,000
Total ...	4,500

and it would seem that the higher members thicken considerably to the westward.

Area.

The Vindhyan area surveyed up to the present time north of the Sone and Nerbudda rivers is nearly 30,000 square miles, and there is further a large tract of more than 10,000 between Sipri and Neemuch not yet surveyed, but known to be occupied by the same formation, so that the whole superficies, where the Vindhyans appear at the surface, is about 40,000 square miles. Besides this, however, the trappean area north of the Nerbudda and east of Neemuch and Burwai, is, as shown by occasional inliers, underlaid, probably entirely, by the same strata. This adds another 25,000 square miles, and brings up the entire area in the North-West and in Central India, where Vindhyans occur, either at or beneath the surface, to some 65,000 or 70,000 square miles. In addition to this again must probably be included very large tracts on the Mahanuddee, the Godavery, and in Southern India, where rocks occur which most likely will hereafter be correlated with the Vindhyans.

Fossils.

As yet no reliable fossils, or indeed anything that can be asserted to be a fossil at all, has been found in either the upper or the lower Vindhyans, although more than one writer has noticed markings of various kinds which they either believed or suggested to be such. It is very doubtful, however, if any of these be organic. Captain Dangerfield* notices in the "fine grained yellowish-brown sandstone slate" of Jirun near Neemuch, the occurrence, "between the slaty fracture, of numerous vegetable remains or impressions of a species of fern, appearing to be in a carbonized state." If the above were really vegetable remains they would be

* Malcolm's Central India, Vol. II, p. 332.

in the plane of bedding and not in the slaty fracture, but it is tolerably evident from the description, that Captain Dangerfield fell into the not uncommon mistake of confounding dendritic markings with impressions of ferns. Not long ago a number of similar specimens from the Bundair sandstone were placed as fossil ferns in one of the exhibitions held in the Central Provinces.

Captain Franklin* speaking of the Bundair limestone remarks "at Nagound (Nagode), in the bed of the Omeron river, its lower and central beds are exposed to view, containing fragments of fossil wood, also fragments of stems of ferns, and one piece exhibited what I took for an impression of the gryphite shell." Franklin's specimens having been long since lost, no means exist of testing their genuineness. Jaquemont was afterwards induced by his paper to search at Nagode for fossils, but without success. Mr. H. B. Medlicott also visited the place in 1856, and observed certain markings bearing a resemblance to organic forms, but he was inclined to doubt their being such in reality. His views regarding them and Franklin's specimens may be found in the Memoirs of the Survey, Vol. II. p. 53.

Mr. J. Hardie also, in his sketch of the Geology of Central India,† states that organic remains are numerous in the limestone of Neemuch. He was not, however, able to refer any of them with certainty to any particular genus, though he makes some suggestions on the subject. It is not possible to determine them from the figures and descriptions he gives of three of them, and it indeed seems more than doubtful whether they be organisms at all. In the sandstone of that country, Mr. Hardie observed no fossils except one specimen, which appeared to him "to be the impression of a portion of a cryptogamus plant." A very strange structure is also often observable on the weathered surface of the Dholpur (Bundair) limestone, but there is the same difficulty in arriving at any definite conclusion as to its being organic

* Asiatic Researches, Vol. XVIII, p. 28.

† Asiatic Researches, Vol. XVIII, part II, page 43.

or not. It will be remarked as a somewhat suggestive fact, that most of these pseudo (?) fossils have been observed in the limestone of the upper Vindhyans.

Age.

When describing the lower members of the Vindhyans, it was shown that they rested with complete unconformability on the older series with which they are brought in contact along their margin. Typical cases were mentioned:—In the Sone valley where the lower Vindhyans repose on the slate series totally unconformably, and in Gwalior where the valleys in the previously disturbed and denuded strata of the Gwalior series are filled up by masses of the Kymore sandstone and conglomerate. The Vindhyans are also seen in superposition to the Bijawurs, but the unconformity is there less clearly marked. The Gwaliors and Bijawurs themselves rest unconformably on the gneiss, and hence it is unnecessary to say that the Vindhyans, where in contact, do so also.

The age of the Vindhyan series, relatively to the stratified formations newer than itself, cannot be determined by the test of superposition; for, notwithstanding the immense area covered by these rocks, no more recent deposits anywhere overlie them, except such as are known to be *vastly* younger. The great coal-bearing formations are nowhere found to repose on them. Palæontological evidence also fails us, as hitherto every investigator has failed to procure a single reliable fossil or known form. The only direct evidence we have is the occurrence in the Talchir conglomerate of pebbles from the Vindhyans. This, however, assuming the genuineness of the pebbles, of which there seems to be no doubt, is perfectly conclusive. Indirectly corroborative we have the altered aspect of the Vindhyans in some parts, the Dhar forest for instance, where much of the sandstone is converted almost into quartzite, with the absence of anything like metamorphism in the coal rocks, and the absence of organic

remains, which are more or less abundant in the newer formations. The Vindhyans are in the Indian scale mediate between the Bijawurs and Gwaliors on one hand (the relative age of which to each other is yet uncertain) and the Talchirs on the other; the first formation beneath the lowest coal as far as we yet know.

With regard to their age according to the European standard there is little to be said, as the absence of fossils deprives us of the only means of direct correlation. In a previous volume* of the Memoirs, however, Dr. Oldham has shown the probability of the Damuda system representing in part the Permian and upper carboniferous periods, which would indicate for the Vindhyans, therefore, some age older than upper carboniferous. It would be curious if Dr. Voysey's guess, made at a time when great importance was attached to lithological similarity, and in which, relying no doubt on the fact of their being to some extent *red sandstone,* he assigned them an "old-red-sandstone" age, were after all to prove correct. The opinion of the majority of the earlier observers that the series represents the "new red" is clearly erroneous.

Denudation.

The Vindhyan area, especially in the eastern districts, presents a fine field for the study of denudation. The battle between the advocates of marine and sub-aërial denudation has of late been waged so hotly, that it may not be without interest to offer a few remarks on the subject. When commencing the examination of the Vindhyans some years ago, the prevailing opinion was that the physical features of the country were due, if not in detail, at least in all the more important points, to marine action, and the various escarpments were regarded as ancient sea cliffs. It was then believed that the former marked so many periods of rest in the elevation or depression of the land. That the Bundair scarp, for instance, was cut out when the land stood at a certain level, after

* Vol. III, p. 207.

which the latter having risen several hundred feet, a new coast line was originated in the Rewah scarp; and in the same manner by a subsequent movement the Kymore came into existence. Before stating the objections to this theory it will be well, however, to discuss the minor features or details of denudation.

The escarpment of the Kymore range which faces the Sone for more than 200 miles between Rotasgurh and Bilheri is a nearly straight line for the entire length, without any indentation except the curve at Bidjigurh. The northern escarpments, however, the Kymore from Sasseram westward, and the Rewah westwards from Adaisar hill, are deeply indented by intricate, ramifying gorges. Those who support the marine origin of valleys would no doubt explain this by saying that both north and south escarpments are old coast lines, but that the prevalent winds and oceanic currents had in the main a southerly direction, and by them have been produced the irregularity of outline on the north, while the southern coast protected from these has been denuded in a comparatively straight line. Deferring for the moment the origin of the escarpments themselves, it seems perfectly clear that the details have been cut out by sub-aërial action. The southern escarpment being a line of special elevation and the dip slope being here 10°—15° to the north, the entire drainage has been determined in a northerly direction. The rivers all traverse the table land and fall over the northern edge. Hence the southern escarpment has been exposed to *no* river action, and the northern escarpments have suffered from the entire drainage, and have in consequence been cut back by the several streams into the long deep gorges the latter now flow through.

If the northern escarpment exposed alternate bands of hard and soft strata dipping at high angles, it would be nàtural to expect that the sea would, in the course of time, excavate the latter to a certain depth. Even then, however, such bays would be simple, not ramifying. Here, however, the conditions are quite different; the escarpment exposes almost perfectly horizontal strata, and the *same* strata along the entire

length, perfectly free from disturbance or faulting of any kind. There is therefore no conceivable reason why the sea should excavate deep gorges like these in one place more than another, and it is difficult to understand how it could do so at all. There could be no oceanic current, and the effect of waves would be slight up such a land-locked gulf after it had reached a certain length. The latter also would tend to widen as well as lengthen the gorge, the resistance of the rock being equal on all sides. As has been well observed by a recent writer,* the "assumption that currents, whether of wind or water, can move up and take effect at the extremity of a *cul de sac* is fallacious; you may as consistently assume a power to make the smoke pass up a chimney with the top closed; ***there can be no motion without a thoroughfare*......**With respect to the assumed erosive action of currents, even if any large proportion played against the coast, they would be unable to make a deep inlet, for motion cannot take place up a *cul de sac*; a 'cushion of still water' would fill the recess, deflecting the current at its mouth, and thus neutralize its excavating power; furthermore, all the persistent currents of the ocean are on a scale altogether disproportionate to the details of coast outline, and for the most part take grand sweeps parallel with the coasts." If the above be true in general, how much more so when the denuding power of the ocean can derive no assistance whatever from unequal resistance of the rocks themselves.

Furthermore, how is it that in an intricate system of ramifying gorges like that of the Doorgowtee, the head of each separate gorge is also the fall of a stream from the table-land above? If these gorges had been excavated by the sea, why should they thus coincide exactly with the drainage of the table-land? Why should not the rivers sometimes fall into them at the side instead of invariably at the extremity as they do? Any one who has been at the various falls will probably come to the conclusion that in erosive power the rivers are quite competent to do the work, with a climate like the present one. Taking the

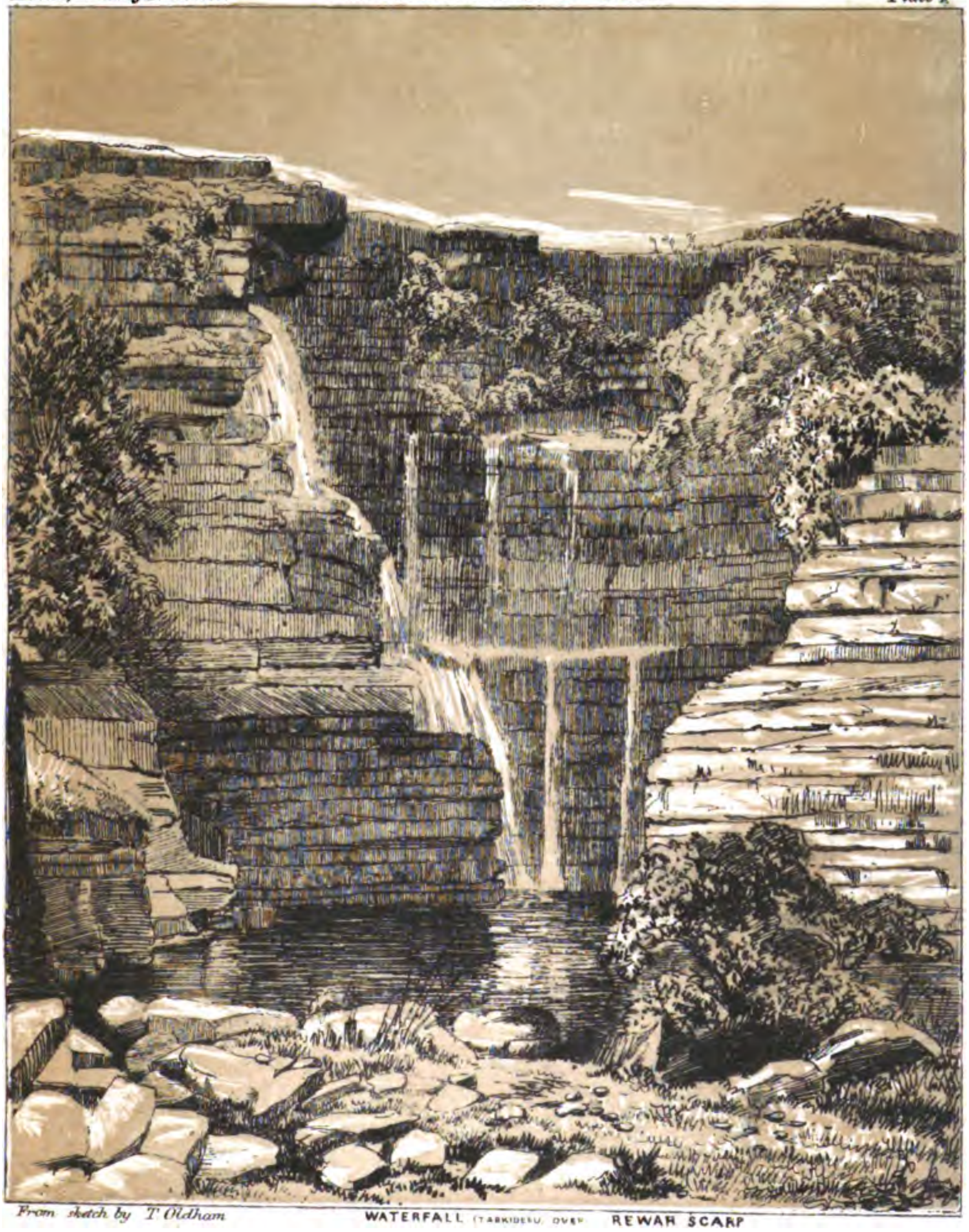
* G. Maw, Esq., F. G. S., Geol. Mag., Vol. III., pp. 441 and 449.

Beehur as an example, it is seen from the twigs and straws left in the branches of the trees near the bank, that in the rains the water goes over the edge several yards deep, and with a breadth of several hundred feet.* Such a mass charged with detritus, coarse and fine, and with a clear fall of 360 feet, cannot but be possessed of great erosive power. The quantity of water in some, and the fall in other rivers, is even greater.

The minor gorges have often no *permanent* waterfall at the head, but the latter is by no means essential to their formation, although when a powerful stream falls from above, the gorge will be much larger. In almost every case, however, there is a dry channel of greater or less length above the head, which becomes filled after rain. Sometimes the heads of two gorges are close to each other, with a mere neck of table-land between; the great Deccan road passes along one of these shortly after reaching the top of Kuttra ghât. Supposing the gorges marine, there is no explanation of these necks except that in every instance the denuding action *chanced* to cease just before the neck was cut through. But assuming them sub-aërial, there is the very obvious reason that, as the heads of the two gorges gradually approached each other, the lengths of the streams above would become shorter and shorter, and consequently their drainage and eroding power less and less, until, when the intervening rock became very narrow, the action would be little more than pluvial.

Purely pluvial action on the same extent of surface would, of course, be much less powerful, but examples of what it can effect in time are frequent amongst the Vindhyans. Thus at Ponree, three miles south of Myhere, there is a pointed hill rising 450 feet in height above the plain, formed entirely of horizontal Sirboo shales. The base of the upper sandstone is here 600 feet above the same level, so that 150 feet of shales have been removed, but still many moderate sized pieces of sandstone remain on the hill. Any violent action like that of waves would at once remove

* At Rewah there is a fall of twenty feet, which is superficially obliterated after a heavy fall of rain from the body of water passing down.



From sketch by T. Oldham

WATERFALL (TARKIDERU) OVER REWAH SCARP

Near Mirzapur

Photozincographed at the Surveyor General's Office Calcutta.

these, and it is evident to an observer on the spot that the shale has been gradually cut from under them by the wash of rain. In other cases several hundred feet of rock have been removed in a similar manner.

A most striking case in favour of sub-aërial denudation occurs in the large valley which one enters from Kuttungee. It is twenty miles long by about eight broad, enclosed on every side by the Bundair escarpment, 500 or 600 feet in height, except on the south-east, where it is bounded by the equally high ridge of vertical Rewah sandstone. In the centre, where the strata have a quaquaversal dip, we find an irregular circle of smaller hills along the outcrop of the lower Bundair sandstone and limestone; the valley itself being mainly cut out of the Sirboo shales which are capped along the escarpment by the upper sandstone. The only entrances to the valley are the very narrow gorges of the Kair and Bhudur streams and those at Kuttungee and the north-eastern end. (See Fig. 11.) If

Fig. 11. Valley north-east of Kuttungee. AA, Bundair escarpment: BB, Rewah ridge: CC, Hills along outcrop of lower Bundair sandstone and limestone.

the valley were marine, it is only by these entrances that the sea could have gained admission, and it is perfectly inexplicable how it could have

excavated and removed many cubic miles of matter from the interior of this land-locked gulf, and yet have left intact the same strata at the entrances, exposed to the full force of the open sea. It is necessary to suppose that the sea in a state of comparative quiescence should have incomparably greater denuding power than the sea in its full force, acting in both cases on the same rocks; for if otherwise, the scarp at Kuttungee must have been carried away long before the valley could have been excavated to its present dimensions. The sub-aërial theory is encountered by no difficulty of this kind, and it at the same time accounts (according to the now well known explanation of such phenomena) for the gorges themselves, as well as the valley, during the formation of which the system of drainage was clearly nearly the same as that which exists at present.

If the above conclusion be admitted, it follows that some fifty miles of escarpment have been cut out by sub-aërial action; if this then be capable of producing fifty miles, there seems no reason why it could not produce 200 or 300 miles, or any of the escarpments of the Vindhyan area.

There is another argument in favor of the Bundair scarp being sub-aërial. On glancing at the map, it will be seen that the rivers of the Rewah plateau, after leaving the lower Bundair strata, flow for a few miles across the upper Rewahs before falling over the Rewah escarpment. From the edge of the latter, there is a slight inclination of the ground to the south corresponding with the dip of the beds, which is, in all probability, the original inclination of deposition.* The result is that if the present gorges were filled up, the rivers would have to flow up hill one or two hundred feet from the boundary of the lower Bundairs to the edge of the escarpment. The slope having existed *ab initio* could not have been produced after the gorges were cut, by subterranean movements, nor can the case be explained by a great lake occupying the Rewah plateau, as, putting other considerations aside, it must necessarily have had as many

* Memoirs, Vol. II, p. 57.

outlets as there are gorges. The production of the latter in their *commencement,* until the slope in question was cut through and the rivers in a position subsequently to finish them, might also be attributed to marine action,* but besides complicating the affair by the introduction of both marine and sub-aërial forces at different epochs, there are at least two objections to the marine part of it. The Kymore range to the south would have been exposed to the same action, and if the gorges in question were partially marine, we should expect to find oceanic gorges through it also, but none such exist. Further, every gorge of those we are discussing is now the path of a river, while we might naturally expect to find some which were not so, if they were produced in a way unconnected with the present drainage. The only remaining explanation is, that the gorges are due entirely to sub-aërial causes, and that when they were commenced, the lower Bundair area generally was from one to two hundred feet higher than it is now, this amount having been subsequently sub-aërially denuded. If then so much has been effected in this way, is it not simpler to suppose that the whole denudation, from 500 to 800 or 900 feet, has been effected in a similar manner, than to bring in marine denudation to do part of a work, a considerable portion of which was done by sub-aërial denudation? If the latter could remove 200 feet of strata, it could remove 800. If it carried away the lower 200 feet, it must have formed so much of the base of the Bundair escarpment. And if a marine scarp had been previously in existence, the sub-aërial forces must, (unless they chanced all along its entire length to eat exactly up to its base, neither more nor less,) either have left in places a second, outer, escarpment, which they have not done; or else they must have cut back the marine escarpment more or less, which would prove that they had the power of forming such an escarpment themselves. If the scarp again were marine, the Vindhyan area must have been submerged since

* The production of such a gorge open at both ends would, of course, be essentially different from that of a *cul de sac* like the complete gorge.

the period of the rock-laterite because that rock is now found capping outliers separated many miles from the escarpment, but such submergence, if it ever occurred, has left no collateral evidences of its existence.

The escarpments exhibit the usual tendency to conform in direction with the strike of the strata, when the latter are not strictly horizontal. Amongst many fine examples of this, a good one occurs at Hoshungabad, where the strike of the Rewah sandstone, after observing a steady east to west direction for twenty miles, suddenly turns round to north-west—south-east, and the same alteration immediately takes place in the direction of the scarp. The *form* of the escarpments also depends much on the bedding. When the latter is horizontal, and still more when it dips from the former, the escarpment is nearly always precipitous above, with a steep talus-covered underslope; but when, as rarely happens, the beds dip towards it, it degenerates into an easy slope from top to bottom. The form is also influenced by the relative proportion of shale and sandstone, of hard and soft beds. The Kymore and Rewah escarpments are bolder than the Bundair on account of the greater hardness and massiveness of the strata.*

* Vide p. 18.

CHAPTER VIII.—ECONOMIC GEOLOGY.

It is not in an accumulation of sandstones, shales, and limestone like the Vindhyans that one would expect to find much metallic wealth, and as yet none such has been discovered. Their mineral resources, with one remarkable exception,—the diamond mines of Punna,—are chiefly confined to building stones and limestones.

Diamonds.

When describing the Rewah group, the characters and position of the diamond-bearing layer were pointed out. Mr. H. B. Medlicott also, in his report on the Vindhyans of Bundelkund, had previously discussed the geological aspect of the question.* The economic geology of the diamond deposits has been already so fully treated of by Franklin† and Jaquemont,‡ who give ample details of the mode of working and extraction of the gems, the various kinds of diamonds found, the value of the mines, &c., that it would be useless to enter into the subject again. Giving, therefore, references to where the above information may be found, we shall pass on to the humbler, but far more important, resources of the formation.

Limestones.

The limestones consist of the lower Vindhyan and the Bundair. Of the former, it is chiefly the Rotasgurh limestone that is worked, not from any superiority over those lower in the series, but from the circumstances of its topographical position. It is largely quarried and burned in the neighbourhood of Rotasgurh itself, and supplies the surrounding districts extensively, being brought down the Sone in boats, and thence up and down the Ganges. The most northerly outcrops are at present (1869) quarried under European superintendence for the Sone canal works at Dehree.

Attempts have been made to utilize this limestone for lithography, specimens having been sent to Calcutta by Lieutenant Sherwill

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* Memoirs, Vol. II, p. 65.

† Asiatic Researches, Vol. XVIII, p. 100.

‡ Voyage dans l'Inde, Tome I, p. 399. The mines have also been described by Dr. Adam, Jour. Asiatic Society, Bengal, Vol. XI, p. 399, and by Dr. Hamilton, Edinburgh Philosophical Journal, Vol. I, p. 49.

for trial, but they were declared to be "too silicious and too thin for any practical purpose." In many of the quarries about Rotasgurh and Sasseram, the upper few feet of rock consist of a white or yellowish, soft, porous friable material, which is employed as *kurree muttee.* The bedding where it occurs is flaggy, and the lateral transition of the same layer from the ordinary limestone into this material, may be traced in places, so that the latter is clearly formed by the alteration of the limestone. Analysis by Mr. Tween of two specimens (not however taken from the same layer) gave—

	Limestone.	Porous rock equal in weight to limestone.	Porous rock equal in bulk to limestone.
Loss on ignition, after restoring CO^2 (chiefly water and organic matter)	17·2	3·2	1·28
Iron and alumina	8·0*	5·6†	2·24†
Carbonate of lime	40·0	·6	·24
Carbonate of magnesia	13·2	·2	·08
Insoluble in nitro-hydrochloric acid (chiefly sand and clay)	22·4	90·8	36·32
	100·8	100·4	40·16

showing that the lime and magnesia as well as the water and a portion of the iron and alumina of the limestone have been removed from the porous rock which consists almost entirely of that portion of the limestone insoluble in nitro-hydrochloric acid.

A variety of rock, often called chalk, is found in the neighbourhood, which, amongst other uses, has been employed in the manufacture of soda water, the analysis of which afforded Mr. Tween about 25 per cent. of insoluble matter, the remainder being chiefly carbonate of lime.

In the Sone valley, where the lower Vindhyan limestones are principally developed, there is but little demand for lime owing to the wild character of the country, but to the extreme west, at Moorwara, quarries have been opened where the Jubbulpur railway crosses the outcrop. The Moorwara rock is the same as that at Rotasgurh. In Bundelkund the lower Vindhyan limestones supply local requirements, but owing to the want

* Chiefly alumina. † Chiefly iron.

of water carriage or good roads, the lime is not transported to any distance.

The Bundair limestone supplies the Jubbulpur railway for a large portion of its length, the latter crossing the outcrop near Sohawel, and running along it for thirty miles from Myhere westwards up the valley of the Tonse. In the Dumoh district, besides furnishing lime, it is much used as a building-stone along the outcrop, being preferred to the lower Bundair sandstone immediately to the south, which is a harsh inferior material, while the limestone is easily trimmed into stones of regular shape. At Hoshungabad the limestone is not worked at all, kunkur from the Nerbudda alluvium being used instead. The rock is as pure here as elsewhere, but it would seem that the European portion of the community at least are not aware of its existence.

In 1843, Captain Shortrede sent to the Asiatic Society one or two specimens of the Bundair limestone from near Rewah, which were submitted to a practical lithographer for trial, and by him reported on very favorably. He found that the impressions from the larger piece came off well, and considered that that quality of stone would answer remarkably well, as it approached nearer the German lithographic stone than any Indian variety he had previously met with.* We are not aware of any subsequent experiments on this rock, but it would seem that the above report, made from a single specimen of small size, and therefore not very conclusive, is of an unduly favorable nature, as the stone has never come into use for lithographic purposes.

Besides the above strictly Vindhyan rocks, about many of the falls over the Rewah and Kymore escarpments large masses of stalagmite occur, deposited by the dripping water. Considerable quantities of very fine lime are burned from it in various places, which is sold at the kilns to the Mahajuns at about 20 maunds per rupee. By them it is transported on pack-bullocks to Mirzapur and other towns. Amongst other

* Journal, Asiatic Society, Bengal, Vol. XII, p. 1120.

places it is worked near Sohagi ghât, from whence we believe the supplies were drawn for the Jumna bridge at Allahabad.

Building stones.

The above resources are however of slight importance compared with the building stone which the upper Vindhyans furnish. They supply the greater portion of the North-West Provinces and part of the Punjab (besides the immense tract actually covered by these rocks) with stone of an excellence unsurpassed in India, and of which are built the finest edifices and cities of the Gangetic valley. Allahabad, Benares, Agra, and Delhi have all drawn their supplies from thence, and of this material have been erected the proudest monuments of the Mogul dynasty. Akbar, for his palace of Futtipur-Sikri and the forts at Agra and Allahabad; Shah Jehan, for portions of the Taj at Agra as well as for the Jumma Musjid at Delhi, and Aurungzeb, for that at Benares, all availed themselves of these resources. Latterly, some of the largest engineering works in India, including the piers of the East Indian Railway bridges over the Jumna at Allahabad and Delhi, have been constructed of this material.

The lower Vindhyans supply no stone worth special mention. The main mass of them consists of shale and limestone which is in great part flaggy. What sandstone there is would in places afford a good material, but wherever these rocks occur a better is obtainable within a short distance from the Kymores. Besides this, the lower Vindhyans, both in Bundelkund and the Sone valley, are in a very inaccessible position.

The Kymore sandstone is worked very extensively. In the neighbourhood of Chunar, which is the most easterly point at which the Railway touches this formation, a great number of small quarries have been opened for the supply of places lower down country, and much is also raised near Mirzapur. Large blocks and flags are both procurable. Very superior stone is obtained from some of these. It is fine-grained and homogeneous, usually yellowish- and greyish-white in color, occurring in beds several feet thick and perfectly free for long distances from any

kind of jointing or fissures, so that very large blocks may be extracted. Some sandstone finds its way from thence even as far as Calcutta, being in use by the undertakers for tombstones, floorings, &c. The stone for the Jumna bridge was obtained from the quarries some miles up the river, and brought down in boats. Mr. Owen, formerly in charge of those at Purtabpur, (from which, and from those at Seorajpoor on the Jubbulpur line, the stone for the new High Court at Allahabad was taken) describes the material as a "fine-grained, compact sandstone, of a light reddish color; it is extremely homogeneous, moderately hard, and suitable for every kind of work, from the large blocks of the Jumna bridge piers, to the elaborate carvings of a church. When first quarried it is softer than it afterwards becomes when exposed to the air." The workable stone lies in beds of from 6 inches to 8 feet in thickness,—extremely fissile in some beds,—the lower the beds, the further they crop out from the hill, and the more compact and homogeneous the stone, generally speaking. The stone is extracted by blasting and by splitting with wedges. The cost in Allahabad of ashlar from these quarries, including all expenses of quarrying, loading, carriage, and unloading, &c., is 10 annas per cubic foot.* The cities of Benares, Mirzapur, and Allahabad, besides others of less note, draw their supplies of building stone exclusively from the Kymores.

The sandstones of the Rewah group are less used than those of either of the other groups. This is due partly to the beds being frequently coarse and harsh, and greatly subject to false bedding, partly to the fact that the Rewahs do not occur much, close to the Gangetic valley or to large cities. Some portions are however of superior quality, and supply all local wants. In the neighbourhood of Hoshungabad, and also in the Sipri and Gwalior districts, thin red flags from $\frac{1}{8}$ to 1 inch thick are much used for roofing. Some of these are true beds, others the laminæ produced by oblique stratification. In one quarry near Hoshungabad, two systems of jointing were observed, forming nearly right angles with the

* Professional papers on Indian Engineering. Roorkee, No. VI.

bedding and each other, so that squared blocks were extracted ready made. The new road and dâk bungalows in the Sipri district are built entirely of stone. The flat roofs are formed of flags supported on long stone joists stretching from wall to wall, and the floors are made of a similar material.

The lower Bundair sandstone is a harsh gritty material, mostly rather coarse-grained and thin-bedded, so that it is never used except for rough work. The upper sandstone on the contrary produces some of the finest stone procurable from the Vindhyans. It is very extensively employed wherever there is any demand for building stone, but the most celebrated quarries are those to the south of Bhurtpur, which have supplied Agra, Delhi,* Muttra, and all the other cities and towns of that region. The Rupas quarries are amongst the best known, and have been worked for a very long period. There are two marked varieties of stone, one a dark-red kind, sometimes purely red, but generally speckled with small yellowish-white spots, or sometimes the white is disposed in streaks parallel with the bedding, or in large irregular blotches. The other is a yellowish-white, very fine-grained rock, perfectly homogeneous both in texture and color. Generally speaking in any one quarry only one of these two varieties occurs, but sometimes both are found interbanded.

The red variety is for architectural purposes much inferior to the white. The irregularity of its coloring greatly mars the effect, as will be recollected by any one who has visited the Taj, where the frequent juxtaposition of red and partially white blocks of sandstone, and the streaked and blotched appearance of others form a most unsightly blemish in that noble and almost faultless mausoleum. Some specimens of the red sandstone also are liable to disintegration from the effects of time, although others are little, if at all, inferior to the white in this

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* Bishop Heber, in his journal, has described the buildings of Delhi as composed of *red granite*, an error which is worth calling attention to, as it has been repeated, on his authority, in more than one more recent work.

respect. Thus, in Akbar's palace at Futtipur-Sikri many blocks have been defaced or crumbled away, whilst others of better selection, after three hundred years' exposure to the weather, retain the sharpness of their elaborately carved surfaces almost as clearly as when fresh from the mason's hands. Beerbul's palace may be selected as an example of what this stone is capable of in the way of elaborate ornamentation when well chosen. This red sandstone frequently possesses a perfectly parallel lamination, by the aid of which, and the introduction of a series of wedges, it can be split up into flags of various thicknesses, which are well adapted, and are largely used, for flooring and roofing. The laminated structure at the same time diminishes the value of the stone as a building material. Some experiments were made on these rocks in 1830 by Lieutenant J. T. Boileau of the Engineers with rather curious results. It was found that while the strength of the dry red sandstone was to the strength of the dry white only as 11 to 17, the strength, when saturated with water, was as 11 to 9; that while the white sandstone lost about half its strength by saturation, the red in this respect remained the same, and hence is peculiarly suitable for roofing purposes. The mean breaking weights of slabs 4½ feet × 12 inches × 1½ inches, the supports being 4 feet apart, and the deflection at the moment of fracture were found to be for*

		Breaking weight.	Deflection.
		lbs.	inches.
Dry...	Red sandstone	392	·537
	White ditto	575	·580
Wet...	Red sandstone	386	·708
	White ditto	300	·791

The yellowish-white sandstone is a splendid material. The thickness of many beds admits of blocks of any required size being extracted, while the fineness and perfect homogeneity of texture allow the execution of

* Gleanings of Science, Vol. II, p. 158.

the most delicate and elaborate carvings. At the same time the uniformity in color, which is of a most pleasing tint, is so great, that the different stones in a building are only distinguishable by their joints. The palace of the Rajah of Bhurtpur at Deeg, which is regarded as one of the most beautiful edifices in India, testifies at once to the excellence of the stone employed and the skill attained by the stone-cutters of that district. Cupolas resting on slender shafts of 2 and 3 inches diameter, arches supported on strong yet graceful pillars, windows formed of single slabs of stone perforated into the most elaborate tracing meet one at every turn. The palace at Bhurtpur is another amongst the many splendid buildings erected of this stone.

The white sandstone is, amongst other uses, largely employed for telegraph posts, for which the red is not well suited on account of its liability to split. These are 16 feet in length, 12 inches square at the lower end and 8 at the upper, the wires being supported by a short cross-piece let into a groove near the top. Similar posts are also manufactured from the Kymore sandstone of Chunar.

As an example of the immense blocks which can be extracted from these quarries, we may mention two monoliths lying on the ground about a mile south-east of Rupas near the quarry from which they were cut. They are of speckled red sandstone, one a circular column 34 feet 6 inches in length with diameters at the ends of 3′ 3″ and 2′ 8″; the other a parallelopiped 42′6″ long by about 5′ 6″ × 4′ 0″ (at the ends 5′ 9″ × 4′ 1″ and 5′ 3″ × 3′ 8″). The contents of the larger of these is about 900 cubic feet, and the weight nearly 60 tons, the specific gravity being 2·32. The villagers call these stones '*gilli danda*' from a supposed resemblance to the implements used in a native game, but know nothing of their history, saying they have been there from time immemorial. Not far from this, about two miles east of Rupas, there are in the temple of Buldeo three prostrate idols which measure in length respectively 28, 21 and 22 feet. The first has a breadth of 7 or 8 feet and they are all formed of single

stones. They are said by the priest in charge to have been dug out of the ground at their present site about 70 years ago by a former Rajah of Bhurtpur.

Iron ore.

The remaining resources of the Vindhyans may be disposed of in a few words. Superficial deposits of iron ore occur scattered over the Kymore table-land, which are worked to some extent. The rock-laterite also, which occurs in outliers on the Punna range of hills, is underlaid by some yards of white and purplish clay containing irregular segregated accumulations of brown hæmatite, which is extracted and smelted to a considerable amount.

Sulphate of iron.

The joints of the black Bijigurh shales are often rusty from decomposed pyrites, and are sometimes filled with veins, one or two inches thick, of the impure mineral. The frequent rusty appearance of the shale itself too, arises from disseminated pyrites. The mineral is granular and very impure, a condition extremely favorable to its decomposition; and hence, especially in places which are damp yet sheltered from rain, as underneath overhanging ledges, a thick efflorescence of sulphate of iron is common, which is collected and exported to a trifling extent.

Absence of coal.

The black color of these same Bijigurh shales led to a belief of the existence of coal in the Kymore hills, the report having been originated by a Mr. Hyland,* and a similar idea was entertained by Franklin with regard to certain black shales of the Lower Vindhyans in Bundelkund. The Bijigurh shales on a weathered surface certainly have in places a remarkably coal-like appearance externally, but the similarity unfortunately ends there as they are perfectly incombustible; they are simply *black shales* and nothing more. The erroneousness of Franklin's conclusion has been already pointed out by Mr. Medlicott.† It is now well known that coal

* *Vide* p. 8.

† Memoirs, Vol. II, p. 91.

does not exist in either Kymores or Lower Vindhyans, or in any other part of the formation.

And of salt.

Salt was also believed to occur in the Vindhyans by some of the earlier observers, chiefly it would appear from the supposed agreement of these rocks in age with the new red sandstone of England. No salt, however, exists in any part of the Vindhyans yet surveyed, nor is there any prospect of its being found. The salt wells of the Bhurtpur district owe their saline properties to the alluvium itself that they are dug in, and even if the mineral were derived from the rocks beneath, the latter are not Vindhyan.

Barytes.

Near Sohagi ghât and at Ginga hill heavy spar, sulphate of barytes, has been found in little strings in the lower Rewahs, but not in sufficient abundance to supply fair cabinet specimens, far less to be of any commercial value.

Fluor spar.

Fluor spar also has been observed in the Bundair limestone, but in too minute quantity to be of any value, beyond indicating the possible existence of the mineral in larger amount.

Chapter IX.—Rocks in other parts of India possibly belonging to the Vindhyan Series.

In the foregoing pages we have confined ourselves exclusively to the description of the Vindhyans north of the Sone and Nerbudda; in other parts of India, however, far removed from the above area, immense spreads of rock exist, which there is more or less probability or certainty will hereafter be found to represent the Vindhyan series. Except in Madras, however, these have as yet been visited only in the most cursory manner, and as little is yet known regarding them with certainty, it will suffice to allude to them in a similar way.

Mr. Medlicott in 1866-67 came upon such beds in the Mahanuddi valley, which may eventually be proved to represent the Vindhyans. The sandstones are strong-bedded, often coarse and rusty, often pure and fine quartzite-sandstones. There are massive, fine, homogeneous clays, often affecting a flat nodular structure (resembling somewhat the splintery clays of the Talcheers); there are also finely laminated silicious shales; these are often calcareous and pass insensibly into finely laminated silicious limestones, in the manner so common with some of the lower Vindhyan bands of the Sone and Bundelkund. These shales seem also connected with fine flaky silicious and quasi-felspathic beds, very hard and compact (porcellanic) on a fresh fracture, but betraying their flakiness by weathering; these beds too find their exact analogues in the lower Vindhyans.

Limestone is perhaps the commonest rock at the surface all over the plains of Chutteesgurh. It is seldom a pure homogeneous rock, being often flaky and earthy-silicious; often also the silicious matter is distributed in strings or in irregular concentric concretions.

It would seem to be only in the most general way that these several rocks observe any order of position. It would appear that all three types may be observed as a bottom rock, resting upon the metamorphics, but there is a decided preponderance of the sandstone in this position.

It would seem that the sandstone never attains a considerable thickness save at or near the base of the series, and it seems probable too that it is altogether absent towards the top. This variability in the deposits is also a point of similarity with the lower Vindhyans, and with the rocks more lately noticed by Mr. Blanford in the Godavery area.

As the most frequent bottom rock, the sandstones are seldom seen in force except near the boundary, but they are nowhere so much developed as in the south-east, resting on the gneiss of the Jonk area and of Sumbulpur, and forming ridges running northwards from that area. If we wanted an appropriate name for the band, the Chanderpur sandstone might be adopted; they have nowhere been seen so well exposed or in so great force as in the ridges running south from the Mahanuddi at Chanderpur.

No constant position for the limestone can be indicated. It seems thoroughly associated with the shales overlying the Chanderpur sandstone.

The position here distinctly assigned to the sandstone is the same as is conjectured by Mr. Blanford for the Pranhita sandstone with reference to the Pein or Pem shales, &c. In the Sone area a quartzite-sandstone is the most general bottom rock of the lower Vindhyans.

To the south of Nagpur, in the region about the confluence of the Weingunga (or Pranhita) and Wurda rivers, Mr. Blanford has recently mapped several large spreads of sandstone, to which the provisional name of Pranhita sandstone has been given. They are found resting on and faulted against the metamorphic series, and in juxtaposition with the Talcheer, Damuda, and Kampti beds, the junctions with which however seem to be all faulted with the exception of that south of Temburwai, which would appear to be a natural one, the Talcheer there resting on the older sandstones. The latter consist of white and purplish quartzite-sandstones, with which sometimes grits, in places felspathic, and conglomerates are associated. Ripple-marks are observable in parts. The strata usually

roll at low or moderate angles, sometimes they are horizontal. To the south of Dewulmurri, some 25 miles below the junction of the Pranhita and Wurda, dark grey silty shales, closely resembling the mudstones of the Talcheers, and micaceous and sandy shales, similar to the Vindhyan shales of the Dhar forest on the Nerbudda, are interstratified with the sandstones; all being quite unaltered.

Occupying a large area in the region about the confluence of the Wurda and Pein Gunga, one therefore distinct from and to the east of that covered by the sandstones, limestones and shales are found (Pein Gunga shales and limestone). The limestone is mostly a dark grey, earthy rock, sometimes pink or buff, generally rather thin-bedded, but occasionally more massive and the stratification less distinct. Chert passing into jasper, sometimes ribboned, is often interbanded. The limestone sometimes weathers on the surface into a peculiar rough wavy form, apparently due to structure. To the north the dip is rather irregular, but along the valley of the Pein Gunga it is nearly or quite horizontal, and is rarely steady for any distance. Numerous faults nevertheless occur, which frequently bring the shales against the limestones. The thickness of the latter would seem to be considerable.

About five or six miles north of Edlabad an excellent section is found in the Satt nuddi, which shows the Pein shales resting quite conformably on the limestone, the two being interbanded at the junction, and in fact passing into each other. The shales are deep red, very fine-grained, with a somewhat nodular structure, and are much but irregularly jointed. Thin beds of limestone frequently occur in them. Both shales and limestones are quite unaltered and no fossils have been found in either. The only place where these rocks and the sandstones were found in contact was near Edlabad, where the sandstone to all appearance dips under the limestone. The boundaries of the shales and limestones with the newer stratified formations, are some of them natural, others faulted.

Sandstones similar to those described are again found in the Godavery valley, and stretch away to an unknown distance to the south-south-west. The shales and limestones have not been observed here.

To the south of the Kistna in the Kurnool district, the earlier observers found a series of nearly horizontal limestones, sandstones and shales which, from their general similarity, but more especially from the fact of their being, like the Vindhyans, the matrix of the diamond, were regarded as being equivalent to the sandstones, &c., of Bundelkund. The recent detailed survey of these rocks by the Madras party of the Geological Survey, by whom they have been named the Kurnool series, rather tends to support this conclusion. A full description of the series will be given in Mr. King's report, which will shortly be published. Many points of resemblance will be observed; but it would be premature to attempt a correlation of the two formations in detail until our knowledge of the vast stretch of intervening ground is more complete.

NOTE.

During the last cold season (1868-69) an opportunity occurred of re-examining some portions of the lower-Vindhyan area in the Sone valley regarding the geological relations of which some uncertainty existed. At page 34 it is suggested, that the bottom limestone of the lower-Vindhyans may, perhaps, not overlie the bottom conglomerate, but pass into it laterally; the calcareous rock being chiefly found in the low ground, and the arenaceous in the higher. It would seem, however, that the more frequent occurrence of the conglomerate in elevated positions, such as the tops of hills, is due to its forming the base of a series of inclined beds. It therefore as a rule outcrops at higher levels; but many cases are met with where a hill-slope is formed of these conglomeritic beds from the summit to the lowest ground, where they are on a level with those of the limestone. Koodyla hill south of Agoree-Khas furnishes an instance of this. The steep western face of the hill exposes slate rocks, but the eastern slope, which agrees in inclination with the dip of the beds, is of the conglomeritic sandstone from the top of the ridge down to the low ground near the left bank of the Rehund. No rock is seen in the river, but on the right bank the limestone comes in in force. Wherever the two rocks are met with in the same locality, the conglomerate is invariably found between the limestone and slates, numerous examples of which may be found along the line of junction of the lower-Vindhyans and slate series eastwards from the Rehund, where both limestone and conglomerate are thrown up at high angles, and where, consequently, the idea of a lateral transition is inadmissible. Such sections may be found at Kujrahut, at Joorwani (about 2 miles to the east,) and near the right bank of the Rehund. Cases occur where the conglomerate is absent, and where the limestone is therefore in contact with the slates, as in one place a couple of miles west of the Kunhur River, and also apparently in the Sone at Agoree-Khas where some pebbly limestone rests on the jasper beds of the slate series. Where, however, both rocks occur together the conglomerate has invariably been observed to occupy the lowest position in the section. The conglomeritic character is chiefly confined to the lower portion, the beds near the bottom being generally a conglomerate, and sometimes a coarse one, while the higher strata are of a fine-grained homogeneous sandstone; the transition from one variety to the other being, however, gradual. Between Agoree-Khas and Burdhee (*vide* page 31), this conglomerate is met with in two or three places, rising in small hills above the alluvium, but it is entirely obscured in the intervals by the latter, or very possibly it is in places absent.

In speaking of inliers at page 44 one such is mentioned as occurring at Sulkhun, north-east of Agoree-Khas. There, isolated in the alluvium, a low hill occurs, in which the strata dip north-east at 10°-15°. Crossing it from south-west to north-east, or in ascending order of the beds, we find, firstly, a brown breccia in which greyish-white angular fragments are included in a dark brown ferruginous matrix; then a thin band

of sandstone which is covered by some thick-bedded limestone with much segregated silica, above which comes some thin-bedded, clear, quartzose, fine-grained sandstone. The breccia at the bottom of the section is remarkably like some varieties met with in the slate series, and hence it was considered to be an inlier of that formation. It seems, however, that it should be referred to the ferruginous beds, mentioned at page 31 as occurring under the limestone No. 2, and is hence a strictly lower-Vindhyan rock.

The origin of the 'trappoid beds' (page 34), is very obscure, but the observations of last season tend to support the conclusion that they are not of truly igneous origin (that they have not originated from a state of fusion). Some parts of the trappoids, as about Hoorkahoorkee, do bear a most remarkable resemblance to igneous rock, and may really be so, but in most places the rock has a more sedimentary appearance and thin bands of it are found (as north of Kujrahut, &c.,) interstratified with the porcellanic beds, and made up in part of angular fragments of rock similar to the porcellanics themselves. These vary in size from a pin's head to half an inch, or sometimes much more, and are imbedded in a felspathic sandy matrix. It is not improbable that the smaller at least of such fragments would have been fused and incorporated into the matrix of the rock if the latter were igneous, for the edges of fine splinters of such are rounded in the flame of a blowpipe. The well marked bedding which some portions of the trappoids exhibit, as well as the thin bands not exceeding a yard in thickness sometimes seen interstratified with the porcellanics, and the absence of vesicularity, furnish additional evidence against their being an igneous (fused) rock. Some varieties occur apparently intermediate in character between the trappoid and the porcellanic beds, and it seems probable that both have been formed from a somewhat similar debris, the porcellanics from an impalpably fine mud, and the trappoids* from less finely comminuted materials. Analyses of two specimens by Mr. Tween, support this conclusion, as they indicate a very similar composition.

	Porcellanic rock.	Trappoid rock.
Soluble in acid	5·5	4·8
Insoluble	94·5	95·2
	100·0	100·0
Silica	86·81	79·35
Alumina	6·25	12·28
Sesquioxide of Iron. Present also as protoxide with a trace of sulphide	8·1	2·5
Lime	0·12	0·14
Magnesia	trace	trace.
Potash	4·1	4·5
Soda	1·0	3·1
	101·38†	101·82

* Those at least having a sedimentary appearance. It is perhaps doubtful whether the highly igneous looking rock of Hoorkahoorkee may not have a different origin.

† Contains also traces of arsenic and copper.

The question of whence the debris has been derived is one open to much doubt. As shown at page 36, there is some reason to connect these rocks with the degradation of the crystalline series. It is, however, not impossible that, though sedimentary, they may still be of volcanic origin, although the absence of any undoubtedly igneous rocks among the lower Vindhyans does not favor this view. The brecciated varieties of the trappoids do, however, bear considerable resemblance to such deposits, and it seems that they and the porcellanics must be referred to one origin. If volcanic, the regularity of the bedding and of the minute lamination of the porcellanics, and the very gradual passage from the latter into ordinary shale and sandstone, would indicate for these beds a subaqueous deposition.

The limestone No. 7, which had previously been mapped from Jaradag to the foot of Mungeysar Hill, has been traced from the latter point up the bed of the Ghàgur stream. From this westwards it is concealed by alluvium as far as the Sone north of Agoree-Khas. Beyond this, although much obscured, its outcrop is easily traceable near the right bank of the river, in the streams which cut deeply into the alluvium and in low hills rising above it. The outcrop re-crosses the Sone east of Hurma, at which village the limestone is seen, as mentioned at page 38.

INDIA.

MINERAL STATISTICS.

COAL.

Exactly ten years since, in June 1859, I had the gratification of publishing the first attempt at a careful or detailed return of the amount of coal raised in India. This return related exclusively to the so called Ranigunj field, and had been prepared with a special object, as bearing on the determination of the very important question referred to me for investigation and report regarding proposals for an extension of the then existing line of railway, so as to afford the largest amount of accommodation to the collieries (*a*).

This preliminary investigation led to a more careful examination of that coal-field, and during the progress of that examination, chiefly by Mr. W. T. Blanford, detailed returns were compiled by that gentleman. These were given with his report in 1861(*b*), and contained detailed statements in a tabular form of the mode of working, number of pits, date of first establishment, steam power employed, thickness of seam of coal, together with numerical statements of the quantities of coal raised during the years 1858, 1859, and 1860.

With these returns from the Ranigunj field, I subsequently incorporated similar returns from all other known workings of coal in India, and thus, in June 1861, the first general return of the out-turn of coal in India was published (*c*).

It was hoped that these statistical returns could have been maintained steadily from year to year. But the pressure of other work was too

(*a*.) "Report on the Raneegunge coal-field, with special reference to the proposed extension of the existing line of railway," issued separately: reprinted with report on "Coal resources and production of India," 1867.

(*b*.) Memoirs, Geological Survey of India, Vol. III, 179.

(*c*.) Memoirs, Geological Survey of India, Vol. III, Art. 3.

urgent, and in the absence of any assistance that could be specially devoted to such enquiries, it was found impossible satisfactorily to continue their publication.

In March 1867, I submitted a brief and general sketch of the position, character and extent of the known coal-fields of India, together with the most accurate returns I could procure of the out-turn of coal for the years subsequently to those included in the first series. This first series had, as I have said, embraced three years, (1858,-59,-60), and I was able (in 1867) to give approximately the results from 1861 to 1866, inclusive (*d*).

In the following year (1868), I had taken the precaution to obtain as full a series of these statistical returns as I could, and it was my full intention to have published these (relating to 1867) at that time. Just then, however, an Assistant was appointed to the Geological Survey, with the special object of preparing and tabulating such statistical returns of not only the coal, but also of all the mineral wealth of the country. This gentleman, Mr. M. Fryar, subsequently visited the Ranigunj field, and then obtained the returns for the year 1868. And all the previously obtained returns (for 1867) were also handed over to him.

I may notice here that from the larger proprietors there is no difficulty in obtaining accurate returns. They have at all times met my application for information of any kind with the most ready and satisfactory compliance; and are fully alive to the importance and economy of introducing newer and better systems of work. The difficulty in obtaining these returns lies with the smaller proprietors, who perhaps delve out a few thousand maunds in the year, and then often abandon the work. Each of these wretched diggings produces an out-turn so small that individually it scarcely affects the total; but being considerable in number, they give, in the aggregate, a by no means contemptible addition to that total.

(*d*.) The "Coal resources and production of India" being return called for by the Right Hon'ble the Secretary of State for India; Calcutta, March 1867.

The returns for 1868 (as well as 1867) being thus in hand before the close of last year, I expected that soon after the beginning of this year we should be able to publish these returns. They have been delayed, waiting for a general report on the mineral resources of the country, which Mr. Fryar was anxious to prepare. This can, however, come quite as conveniently apart from these purely numerical statements.

A very few sentences will suffice to explain these. In the first tables I have given the detailed statements of out-turn for 1867 and 1868. And in the second tables, the yearly out-turn of each colliery is given for the successive years from 1858 to 1868, inclusive, or for 11 years.

So far as known, the total annual out-turn of good coal in India during these 11 years has been as shown—the quantity being given in Indian maunds. I have given also in this table the quantity raised in Bengal alone, as compared with the whole of India, and the quantity imported into Calcutta for the entire series of years. The two latter columns taken together give the total quantity of coal required to meet the consumption of Calcutta and of places supplied from Bengal. This quantity, it will be seen, amounted in 1867 :—

to 1,29,93,912 Mds., or 4,76,841 Tons,
and in 1868 to 1,53,94,420 „ or 5,64,933 „

	Coal raised in all India.	Coal raised in Bengal.	Coal imported into Calcutta.	Total consumption for Bengal.
1858 ...	61,62,319	61,62,928		
1859 ...	99,61,928	99,61,928	12,29,160	1,11,91,088
1860 ...	1,00,88,113	1,00,88,113	4,96,585	1,05,84,698
1861 ...	78,06,252	77,85,085	12,85,203	90,70,288
1862 ...	86,43,843	86,30,843	6,76,687	93,07,530
1863 ...	95,12,174	95,04,975	10,36,407	1,05,41,382
1864 ...	90,46,147	90,32,405	18,18,132	1,08,50,537
1865 ...	88,37,953	88,10,425	16,16,143	1,04,26,568
1866 ...	1,08,34,551	1,07,90,035	9,14,427	1,17,04,462
1867 ...	1,18,61,031	1,18,47,178	11,46,734	1,29,93,912
1868 ...	1,35,62,274	1,34,65,829*	19,28,591	1,53,94,420

* The produce of Assam is included in this.

From this table it appears that the total quantity of coal (so far as tabulated) raised in all India during the year 1867, was 1,18,61,031 mds., or 479,233 tons, and in the year 1868, 1,35,62,274 mds., or 547,971 tons. It is worthy of notice also that of this large quantity, only 13,753 mds. were obtained from any other field than that of Ranigunj in the year 1867; and only 1,11,445 mds. in the year 1868. Nothing can more forcibly show the vast importance of this one coal-field.

A simple inspection of the figures given above will show that, with some fluctuations, the amount of coal raised in this country has, during the eleven years just past, increased rapidly and on the whole steadily, from 61½ lakhs of maunds in 1858 to 127¼ lakhs of maunds in 1868. In other words, the quantity has considerably more than doubled during the lapse of ten years. If we go back still further, we find that in 1850, the total quantity sent away from the Ranigunj field was 22 lakhs of maunds, while in 1868, this out-turn had grown to 126 lakhs, or nearly six times the amount. Few industries can point to such an extension within the same number of years.

I have already had occasion to point out that, although there is a steady demand for the better quality of imported coals for certain purposes, for which the Indian coals are not well adapted, and for sea-going or long voyage steamers, still the amount of coal imported to Calcutta year by year depends much more on questions of freight, dead weight, and of general trade, than on any question merely affecting the demand for, and the supply of, fuel.

The local demand again, from the very fact of its being local, must vary materially from year to year. For instance, during the earlier three or four of those years for which returns are here given, there was a large, but very local, demand for coal, even of an inferior quality, for the works of construction on the East Indian line of railway, which demand almost entirely ceased in 1860. In that year, more than one-

eighth part of the entire out-turn of Indian coal was raised solely for such purposes. And a reference to the figures will show that, in the following year the out-turn diminished by nearly one-fourth of the whole amount to which it had previously attained.

Subsequently, although the demand for works of construction diminished, the line of railway itself was gradually opened up, and the extension of communication led to greater demands for fuel. These demands have continued to increase at a rapid rate, until in 1866, in consequence of the extension of the use of coal instead of wood to the upper sections of the line (the completion of the Jumna bridge at Alláhabad enabling this to be carried out) the demand of the previous year was nearly doubled. The amounts supplied for the use of the locomotive department alone on the East Indian Railway, independently of coal used for other purposes, have been during the last eight years as follows:—

1861	...	9,91,215	1865	...	28,27,953
1862	...	12,29,709	1866	...	50,79,612
1863	...	18,37,717	1867	...	50,60,206
1864	...	26,96,442	1868	...	58,40,759

Thus it appears that this one line of railway alone now requires, for its own consumption only, nearly one-half of the total quantity of coal raised in India. The vast extension of the demands for railway purposes will appear when we state that the total quantity of Indian coal used in the railways which are connected with Calcutta, was in 1867, 63,70,321 mds. and in 1868, 66,20,837 as compared with 9,91,215 mds. in 1861. This is independently of imported, or English coal, used for sundry purposes.

I showed in 1867 that, disregarding the very large increase in the demand for coal for railway purposes, there had been a continuous and steady *decrease* in the amount of coal raised in India since the year 1863. This diminution went on up to the year 1867. But I am glad to see that this decrease in the amount of out-turn for purposes

other than railway uses has ceased, and, with improvement in general trade, there has been also an extension of the demand for coal.

Taking the same years as before, we find the—

	Amount of Coal raised in Bengal.	Amount of Coal used by East Indian Railway for locomotive purposes.	Balance.
1861	77,85,085	9,91,215	67,93,870
1862	86,30,843	12,29,709	74,01,134
1863	95,04,975	18,37,717	76,67,258
1864	90,32,405	26,96,442	63,35,963
1865	88,10,425	28,27,953	59,82,472
1866	1,07,90,035	50,79,612	57,10,423
1867	1,18,47,178	50,60,206	67,86,972
1868	1,34,50,829	58,40,759	76,10,070

Or if we take the total railway consumption for the only two years for which I have returns, we will find that the amount left for use in other ways in 1867 was only 50,51,618 and in 1868, 59,90,069. The returns on which this is based will be found further on.

Another view of these numerical results will also tend to show the vast increase in the development of this important Ranigunj field. In 1860, the total number of steam engines in use in this field was 28, with an aggregate horse-power of 490, while in 1868, we have a return of 61 engines with an aggregate of 867 horse-power. That is the number of engines has more than doubled in eight years. It is not so satisfactory to see that the horse-power has not doubled, inasmuch as this indicates a more frequent use of small engines, and probably, therefore, of small workings, or open quarries. It is at all times more economical to work with engines having power to spare than with such only as are equal to the work required of them, when strained to their utmost duty. But independently of this want of attention to economy in the use of steam power itself, the multiplication of small and nearly surface workings is most objectionable.

It may be interesting, in connection with this consideration, to see what proportion the out-turn of the larger companies bears to the whole. In 1868, the Bengal Coal Co. raised 61,39,105 maunds; Gobind Pundit, Sirsole, 24,28,428; the Beerbhoom Co., 13,62,635; the Equitable Coal Co., 11,60,292, and the East Indian Coal Co., 8,30,605, these five companies thus giving an out-turn of 1,19,21,065, out of a total of 1,34,50,829.

With reference to the few localities outside the Ranigunj field, where coal has been raised in India, I would add a few words. Of those in the Nerbudda valley, the coal at and near Lameta Ghât (although only offering prospect of a very limited supply of inferior coal) has been worked very spiritedly by Mr. Walker, railway contractor, chiefly for local use, brick burning, &c. The coal in the Sher river, which is of the same geological age as that at Lameta, has also been worked by the same gentleman. At Mopani, it may be said that little coal has been raised, but active and efficient preparations have been made, so that, on the opening of the railway, the colliery will be able to turn out some thousands of tons per month.

Near Chanda, (at Googoos) south of Nagpore, a little coal has been raised from a pit sunk there, chiefly for trials. This proved to be very inferior coal. It was tried on the G. I. P. Railway (Bombay), but reported to be quite unfit for locomotive purposes, and unable to give a welding heat in the fires. A systematic examination of this field (Chanda) has been undertaken by Government, to test the extent, thickness, and quality of the coals there to be met with, and the results will be published from time to time.

The use of Assam coal does not appear to have extended much. And there seems to be still considerable difficulty, from the want of facilities of communication with the Burhampooter, in bringing this coal into general demand.

A very considerable amount of coal has been raised from some of the beds of the Bokaro field, near Hazareebaugh, which has all been

used in burning bricks, lime, &c., at Hazareebaugh and Gya, but I have not been able to obtain any trustworthy return of the amount. A very limited quantity was also raised in the Palamow field, but it may be neglected as scarcely affecting the total.

I am indebted to the courtesy of the agents of the principal lines of railway in this country for returns of the amount of coal used on the respective works and lines during the year 1867-68. Those lines, the terminus of which is not at, or in connection with, Calcutta, are supplied almost entirely by imported coal. Of these companies, the Madras Railway used in 1867, 6,523 tons 5 cwts. 0 qr. 10 lbs.; and in 1868, 4,500 tons 11 cwts. 2 qrs. 13 lbs., imported direct, and 1,285 tons 12 cwts. 9 qrs. 9 lbs., bought in India. This bought coal had, however, with the exception of a small portion of Australian coal, been imported from England. The Scind Railway used in 1867, 5,578 tons of coal and 67 of coke; and in 1868, 3,836 tons of coal, 27 tons of coke, and 153 tons of patent fuel, making a total, in 1867, of 5,645 tons, and in 1868, of 4,016 tons—all of which was imported from Europe. The great Indian Peninsular line consumed in 1867 and 1868, 116,824 tons, all of which was imported.

On the other hand, those railways which have a terminus in, or connected by rail with, Calcutta are supplied almost entirely by the Indian collieries, using only a very small quantity of imported coal, and that chiefly for "smithy" purposes, &c. Thus, out of a total consumption in the two years of 447,644 tons on the East Indian Railway, only 4,029 tons were imported coal. In 1867, their consumption was 217,557 tons 4 cwts. 5 qrs. 20 lbs. of "country" coal, and 2,809 tons 6 cwts. 2 qrs. 3 lbs. of imported coal, used solely for the workshops. In 1868, 226,077 tons 7 cwts. 2 qrs. of Indian coal, and 1,220 tons 4 cwts. 0 qr. 20 lbs. of imported coal. On the Eastern Bengal Railway in 1867, 16,110 tons 2 cwts. 3 qrs. of Indian coal were used, and no imported coal. In 1868, the same line used 16,330 tons 10 cwts. 0 qr.

22 lbs. of Indian coal, and 573 tons 12 cwts. 3 qrs. of English (chiefly in the river steamers). Only Indian coal was used on the Calcutta and South-Eastern line or on the Municipal Railway. The Delhi and Punjab, for the line from Delhi to Umballa, used only Indian coal from the Ranigunj field. On the Lahore and Umritsur portion of the Punjab line, a small quantity of coal from near Pind Dadun Khan, in the Salt range, was used. The storekeeper reports that the greater part became useless from exposure to the sun, crumbling into dust. It was seldom used, except in company with wood. The total quantity used was only 720 maunds 20 seers.

CALCUTTA,
June, 1869.

T. OLDHAM.

No. I.

RETURN of COLLIERIES worked in INDIA *during the years* 1867-68, *with Statistics of methods of working, out-turn of Coal, &c.*

Name of Colliery.	Method of working.	Number of Pits.	Date of Establishment.	Out-turn of Coal during the Year 1867.	Out-turn of Coal during the Year 1868.	Steam Engine and Horse power, 1868.	Thickness of Seam in feet.	Thickness of Coal worked.	Persons employed, 1868. Men.	Persons employed, 1868. Women.	Remarks.
				Mds.	Mds.						
Babusol ...	Pillar & Stall	2	1858	2,43,501	2,77,374	1 of 20 H. P.	17 13	9	214 Daily.		Steam Coal 2,57,599¾, Rubble 31,519¾ feet in 1867.
Ditto B. C. C. ...	Ditto ...	2	1858	...	2,77,374	1 of 20 H. P. ...	13	9	214		
Banali ...	Pillar & Galleries ...	6 Shafts 2 Quarries 6 Pits ... 3 in work	1859	3,09,118¼	2,86,974¼ from Feby. to Sept. 1868.	1 of 25 H. P. 1 of 12 H. P. 1 of 10 H. P.	10' 6" 11 0	7 feet	300	120	
Bansra ...	Pillar & Stall	1 Shaft ...	1862	7,740	18,930	1 22 H. P. 90 Horizontal.	8	6	...	...	Closed.
Beldangah ...	Ditto ...	2	1862	46,268	1,59,313	1 of 15 H. P.	9' 0 9' 11	9 7	90		Daily.
Bonbahal ...	Gallery & Pillars.	3 Pits ...	1863	2,07,170	1,43,843	1 of 12 H. P. ...	14 feet ...	8 feet	100	80	
Chaptoria ...	Coal carried out by coolies.	3	1857	16,278½	47,923	None ...	20	6 to 10	...	...	
Charnpur ...	Pillar system and gins ...	4 Shafts	1865	2,16,863	2,78,600	1 of 18 H. P. ...	19 16 to 20 15	10 Full thickness			
Ditto Quarry ...		3 Quarries	1866	81,764	......	....					

Chinakuri ...	Pillar & Stall	2	1834	2,20,126	2,30,044	1 of 20 H. P. 1 of 8 H. P.	6½	6½	185		
Chokidangah ...	Gallery & Pillars.	8 Pits ... and 1 Quarry	1836	15,12,330	10,16,449	1 of 7 H. P. 1 of 5 H. P. 1 of 24 H. P. 1 of 13 H. P. 1 of 14 H. P.	14 to 32	6 to 25 ft.	450	200	
Damulia ...	Quarries ...	2 3	1824	......	4,58,024	1 Port. 10 H. P.	16	16	200		
Dhadkia ...	Pillars & Galleries ... Quarry ...	2 Shafts... 3 Quarries	1857	2,11,431	1,92,398	1 of 12 H. P. 1 of 6 H. P.	10 11	8 9	150	100	S. Coal, 1,76,192¼, Rubble 35,238¼ in 1867.
Dhosul ...	Pillar & Stall	8 Pits ...	1853	2,07,000	1,48,000	1 of 12 H. P. 1 of 8 H. P. 1 of 40 H. P.	32	812	75	85	There are 8 pits, out of which two are working, but not always. Two stopped after cutting stone, and two others are cutting stone.
Ditto ...	Ditto ...	...	...	......	......	....	30	18			
Dumarkunda ...	Ditto ...	2	1858	85,355	3,14,952	1 of 10 H. P. 1 of 8 H. P	10	10	155		
Furridpur ...	Ditto ...	6	1859	22,431	21,431	1 of 10 H. P. ...	12	9 10	20	30	
Gharooe ...	Ditto ...	2 Quarries	1866	74,533	......	....	15	Full thickness is worked.			
Harispur (Madubpur)	Ditto ...	5 6	1857	4,82,068	7,02,333	1 of 20 H. P. 1 of 10 H. P.	13	9	378		Daily.
Hurripur ...	...	...	...	......	......	1 of 17 H. P. Beam Engine	...	...	...	...	Will be at work in a few months.
Jemeri ...	Pits & Quarries.	5 Pits 1 Quarry	1859	9,23,375	9,21,061	1 of 25 H. P. 1 of 16 H. P.	20	9	180	200	
Jote Janaki (Mr. Booke)	Pits ...	6	1862	1,25,894	......	1 of 10 H. P. ...	...	8	...	...	No return, 1868.
Kasta ...	Pillar & Stall	2 Quarries	1857	......	......	....	24	24	...	...	This Quarry was closed owing to there not being facilities to bring the coal to market.
Lal Bazar ...	Quarry ...	1	1866	......	1,28,408	....	...	...	160	60	

No. I,—*continued.*

RETURN of COLLIERIES worked in INDIA *during the years* 1867-68, *with Statistics of methods of working, out-turn of Coal, &c.*,—continued.

NAME OF COLLIERY.	Method of Working.	Number of Pits.	Date of Establishment.	Out-turn of Coal during the year 1867.	Out-turn of Coal during the year 1868.	Steam Engine and Horse Power, 1868.	Thickness of Seam in feet.	Thickness of Coal worked.	Persons Employed, 1868. Men.	Persons Employed, 1868. Women.	REMARKS.
				Mds.	Mds.						
Mahomedpur ...	Quarry & Pits	2	1857	16,061	45,792	1 of 15 H. P. ...	14½	7	76		Daily.
Mungulpur ...	Pit worked by Pillars & Stall ...	1	1859	42,697	5,089	1 of 10 H. P. ...	13 to 15	13	72		Ditto.
Ditto ...	Pillars & Galleries.	4 Shafts 2 Quarries 1 P. Pit 7 Working	1839	5,02,035	4,68,342	1 of 25 H. P. ... 1 of 8 H. P. ... 1 of 12 H. P. ...	Coal 11 Slate 5	7 feet 5 floor	225	150	S. Coal 4,12,587½ Rubble 89,447½ in 1867. One engine (25 H. P.) now working.
Nakrajore ...	Quarry ...	......	1866	....	40,000	....	8'—10'	6'—9	65	50	
Newcastle Coal Co. ...	....	......	...	....	......	....	...	...	...	...	No returns.
Nimcha ...	Pit ...	5	1859	6,41,696	10,70,032	1 of 8 H. P. ... 1 of 15 H. P. ...	20 17½	13	607		Daily.
Ditto Quarry ...	Quarry ...	1	1865	2,69,410	....	......	20	20	...	...	
Ninga ...	Pillar & Stall	3 Shafts ...	1862	1,46,393	1,29,710	1 of 14 H. P.... Portable ...	12	7	...	...	
Purliharpur ...	Pit worked by Pillar and Stall ...	2	1856	1,00,246	2,81,708	1 of 15 H. P. ...	9 10	9 10	223		

Puronahdih ...	Pillar & Stall	2 Shafts ...	1863	2,63,826	2,19,060	1 of 35 H. P. ...	10	8			
Ranigunj ...	Pit worked by Pillar and Stall ...	4 6	1816	11,90,087	15,10,987	2 of 32 H. P.... 1 of 10 H. P.... 1 of 25 H. P....	13 12½	9	777		Daily.
Ditto Quarry ...	Quarry ...	1	1866	2,61,264	9,03,058	1 Portable Engine 8 H. P.	13	13	298		Ditto.
Bogonathbati ...	Pillar system winding gear	5 Shafts 4 work No Quarry	1864	3,11,148	4,22,500	1 of 15 H. P.... 1 of 8 H. P. ... 1 of 6 H. P....	8 to 11	5 to 6	...	...	The thickness of the seam varies; all the pits were not at work through the whole year; some of them were worked for a very few months.
Bogonathchuk ...	Galleries ...	6 Pits ... 4 in work & 2 abandoned	1844	3,82,122	3,41,513	1 of 1 H. P. ...	12 & 14	8 12	205	150	
Sanktoria ...	Pit worked by Pillar and Stall ...	2 3	1860	1,85,244	1,80,449	1 of 8 H. P. ... 1 Portable ... Eng. 10 H. P.	10 11½	10 8	155		Daily.
Satgram ...	Pits & Quarries ...	1 Pit 1 Quarry	1860	3,01,535	3,00,511	2 of 25 H. P. ...	10	6	60	100	
Sibpur ...	Pillar & Stall	1	1865	Closed ...	14,836	1 of 12 H. P. ...	? 22	12 9	30	32	
Sirsol ...	Pits & Quarries ...	6 Pits 3 Quarries	1846	15,35,558	12,06,856	1 of 8 H. P. ... 1 of 12 H. P. ... 2 of 25 H. P. ...	20	10	250 200	300	Gross out-turn comprising large and rubble coal.
Sitarampur ...	Pillar system and gins ...	4 Shafts No Quarry	1864	3,02,757	2,79,100	1 of 18 H. P.... A Hoist of ... 6 H. P. ...	8 to 10 4 to 10	5 to 7	...	...	One of the 4 shafts was stopped after a few months' working.
Toposi ...	Pillar & Stall	4 Shafts ...	1863	4,43,863½	4,63,905½	1 of 12 H. P....	30	18	360	300	

No. I,—*concluded.*

***RETURN** of **COLLIERIES** worked in* INDIA *during the years* 1867-68, *with Statistics of methods of working, out-turn of Coal, &c.,*—concluded.

NAME OF COLLIERY.	Method of Working.	Number of Pits.	Date of Establishment.	OUT-TURN OF COAL DURING THE YEAR 1867.	OUT-TURN OF COAL DURING THE YEAR 1868.	Steam Engine and Horse Power, 1868.	Thickness of Seam in feet.	Thickness of Coal worked.	PERSONS EMPLOYED, 1868. Men.	PERSONS EMPLOYED, 1868. Women.	REMARKS.
				Mds.	Mds.						
NERBUDDA VALLEY.											
Mopani or Chota Jubbulpur ...	By an Incline 1; Level Galleries ... 2; By Pits ... 2	1; 2; 2	1861	13,853	226	1 Stationary 30 H. P.; 1 Ditto 20 H. P.; 1 Portable 14 H. P. } 3	Runs from 16 feet in main engine-incline to 30 feet in top level.	All worked	...	...	These coal mines were opened to supply the Great Indian Peninsula and the upper part of the East Indian Railway. As the former line is not yet opened to Jubbulpur, any quantity of coal is not being taken from the mines: galleries are being driven and every thing placed in readiness: at the present time, five thousand tons per month could be easily supplied. Galleries are set out 10 feet wide. Other 2 thinner seams, but not yet worked.
Lameta Ghât ...	Quarrying ...	...	...	...	63,519	...	4'	4'	4'	...	2,331 tons is the total quantity of coal taken from the pits since the commencement up to 31st December 1868.

Sita Riva ...	Level Working from Nullah ...	2	1867	...	32,700	None ...	20 4	half of each.	...	...	Seams nearly vertical.
Assam.											
Terap ...	Shallow Quarries ...	3	1854	...	7,000	...	7	...	...	...	Formerly worked by Government.
Namdong ...	The coal is merely covered with surface soil	1	1867	...	2,000	...	9	...	...	...	Good coal, contains less sulphur than the above.
Borhaut ...	...	3	1867	...	6,000	...	3½	...	...	...	On the Desang, splits and crumbles away on exposure to the atmosphere.

N. B.—For convenience of reference, the names of the Collieries in the Raniguni field are given alphabetically.

No. II.

RETURN of COAL raised in INDIA *during each year from* 1858 *to* 1868 *inclusive.*

Name of Colliery.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	Remarks.
I.—Localities in the Raniganj Coal Field.												
Assensol ...	20,000	20,000	10,000	...	...	...	...	...	...	...	...	
Babusol ...	...	...	84,000	1,30,311	1.81,634	2,21,231	2,40,984	1,49,723	2,15,223	2,43,501	2,77,374	
Bhagaband ...	...	60,000	2,50,000	...	...	...	...	...	...	...	...	
Banali ...	...	...	30,000	57,700	66,537	2,39,825	54,993	83,061	1,88,311	3,09,118¼	2,86,974¾	
Barabone ...	...	...	10,000	...	...	...	...	...	...	...	...	
Bansra ...	...	1,80,000	70,000	85,098	39,306	...	...	...	...	7,740	18,980	
Ditto ...	...	...	...	...	69,508	1,49,975	1,06,509	18,876	45,343	...	...	
Beldangah ...	...	...	25,000	...	...	...	...	...	...	46,268	1,59,313	
Bonbahal ...	...	...	...	...	...	...	11,570	1,06,669	1,38,954	2,07,170	1,43,843	
Borachuk ...	60,000	60,000	70,000	...	...	1,33,113	1,35,499	...	...	...	...	
Chánch ...	1,41,000	2,60,000	2,80,000	2,31,099	2,36,922	4,96,937	2,20,326	...	...	...	...	Includes Nuchibad and Dumarkunda up till 1864.
Chaptoria ...	...	...	...	...	...	...	...	...	...	16,278¼	47,923	
Charnpur ...	80,000	80,000	...	...	...	2,394	1,41,717	1,59,608	1,58,398	2,16,863	2,78,600	
Ditto Quarry ...	...	...	...	...	...	...	...	...	...	31,764	...	
Chinakuri ...	3,50,090	2,73,000	3,29,000	3,17,502	2,99,329	3,28,842	2,31,563	1,95,438	2,89,012	2,29,126	2,30,044	
Chokidangah ...	3,30,000	4,65,000	2,64,584	2,64,571	3,69,626	3,38,430	5,23,288	8,84,762	14,28,307	15,12,330	10,16,449	
Damulia ...	2,23,000	3,91,000	3,55,500	3,50,000	5,00,000	2,40,000	1,76,568	...	...	...	4,58,024	
Deoli ...	...	...	...	...	...	...	...	...	...	...	...	

Dhadkia ...	...	...	1,00,000	12,618	63,098	83,697	87,384	1,68,420	1,18,764	2,11,431	1,92,398	
Dhamwa ...	...	...	20,000	...	...	...	...	...	...	...	...	
Dhosul ...	...	14,000	...	...	...	...	...	...	...	...	...	
Ditto ...	...	...	No certain record.			...	2,500	1,50,000	4,18,900	2,07,000	1.48,000	
Dumarkúnda(see Chánch)	...	...	...	...	...	...	...	...	...	85,355	3,14,952	
Furridpur ...	...	...	...	...	...	...	...	...	...	22,431	21,431	
Puttipur ...	...	2,00,000	1,50,000	...	...	1,54,986	2,17,968	31,767	...	...	...	
Gharooe ...	60,000	60,000	50,000	...	...	...	27,150	...	...	74,533	...	
Gushik ...	...	50,000	17,099	...	...	...	...	...	...	...	...	
Ditto ...	20,000	10,000	...	...	...	...	...	...	...	...	...	
Harabhanga ...	...	...	1,50,000	...	...	...	...	...	...	...	...	
Harispur (Madhubpur)	58,000	4,43,000	4,40,000	4,67,772	3,66,684	4,07,169	4,86,129	5,78,764	6,64,373	4,82,068	7,02,333	
Hatinál ...	75,000	75,000	2,00,000	1,85,137	2,13,290	2,98,748	2,27,910	70,770	...	...	...	
Harripur ...	...	...	...	...	...	...	...	...	...	...	...	
Jemeri ...	2,50,000	4,00,000	3,64,095	10,71,062	10,67,039	10,91,395	10,83,290	10,53,001	10,50,670	9,23,375	9,21,061	
Jote janaki, (Mr. Booke)	...	55,000	10,000	...	...	...	...	...	1,17,000	1,25,894	...	No return, 1868.
Kasta ...	90,000	60,000	38,892	...	...	...	...	...	...	...	...	
Lalbazar ...	75,000	75,000	...	...	...	...	...	...	...	...	1,23,408	
Mahomedpur ...	40,000	40,000	40,000	...	...	2,208	...	...	7,020	16,061	45,792	
Mainanaggar ...	1,10,000	90,000	1,00,000	...	...	...	...	...	...	...	...	
Mangalpur ...	4,50,000	8,50,000	10,00,000	3,67,476	3,80,880	4,40,568	5,38,410	5.77,021	6,33,954	42,697	5,039	
Ditto ...	...	3,600	33,000	...	16,824	1,82,592	19,096	...	1,52,736	5,02,035	4,68,342	
Nakrajore ...	...	...	...	...	...	...	...	...	...	...	40,000	
Newcastle Co ...	...	...	...	...	...	...	2,00,000	3,00,000	1,50,000	...	...	No returns; the collieries have been working.
Nimcha ...	...	...	70,000	1,78,436	3,34,330	4,35,336	3,73,068	6,46,594	8,85,552	6,41,696	10,70,032	

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No. II,—*continued.*

RETURN of COAL raised in INDIA *during each year from* 1858 *to* 1868 *inclusive,*—continued.

Name of Colliery.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	Remarks.
Nimcha Quarry ...	...	...	...	...	...	...	...	...	...	2,69,410	...	
Ninga ...	2,25,000	2,10,000	76,138	69,012	59,378	87,369	3,32,232	3,41,030	3,57,320	1,46,393	1,29,710	
Ditto ...	...	...	...	...	...	...	...	...	...	...	...	
Nuchibad (see Chánch)	...	...	...	...	...	...	...	...	...	...	...	
Purasia ...	...	...	30,000	23,777	...	...	...	...	...	...	...	
Puriharpur ...	...	1,60,000	80,560	...	37,782	57,984	...	...	...	1,00,246	2,81,708	
Puronahdih ...	...	...	...	...	7,569	8,421	69,839	71,198	15,660	2,63,626	2,19,060	
Ranigunj ...	18,00.000	19,00,000	16,00,000	13,83,510	13,27,020	15,01,960	11,20,152	10,75,014	13,39,535	11,90,067	15,10,987	
Ditto Quarry ...	...	...	...	...	...	...	...	...	32,438	2,61,264	9,03,058	
Bogonath bati ...	...	...	...	...	...	...	...	5,418	1,20,710	3,11,148	4,22,500	
Bogonath Chuk ...	1,00,000	1,75,000	3,00,000	82,974	2,64,270	47,610	2,46,702	60,618	3,93,495	3,82,122	3,41,513	
Samsundarpur ...	10,000	50,000	50,000	...	...	47,800	85,530	55,836	1,91,177	...	...	
Sanktoria ...	...	...	...	...	...	72,450	1,70,654	1,63,468	1,11,338	1,85,244	1,80,449	
Satgram ...	...	...	...	3 18,870	3,59,656	3,30,192	1,14,738	...	...	3,01,535	3,00,511	
Sibpur ...	...	...	...	...	...	...	...	...	...	...	14.836	
Sirsol ...	12,00,000	16,00,000	14,77,789	12,76,303	12,81,113	12,85,403	12,75,331	12,80,290	12,81,202	15,35,558	12,06,856	
Sitarampur ...	1,50,000	...	...	...	...	...	...	57,112	78,499	3,02,757	2,79,100	
Sripur ...	...	10,000	4,000	...	...	...	...	...	...	...	...	

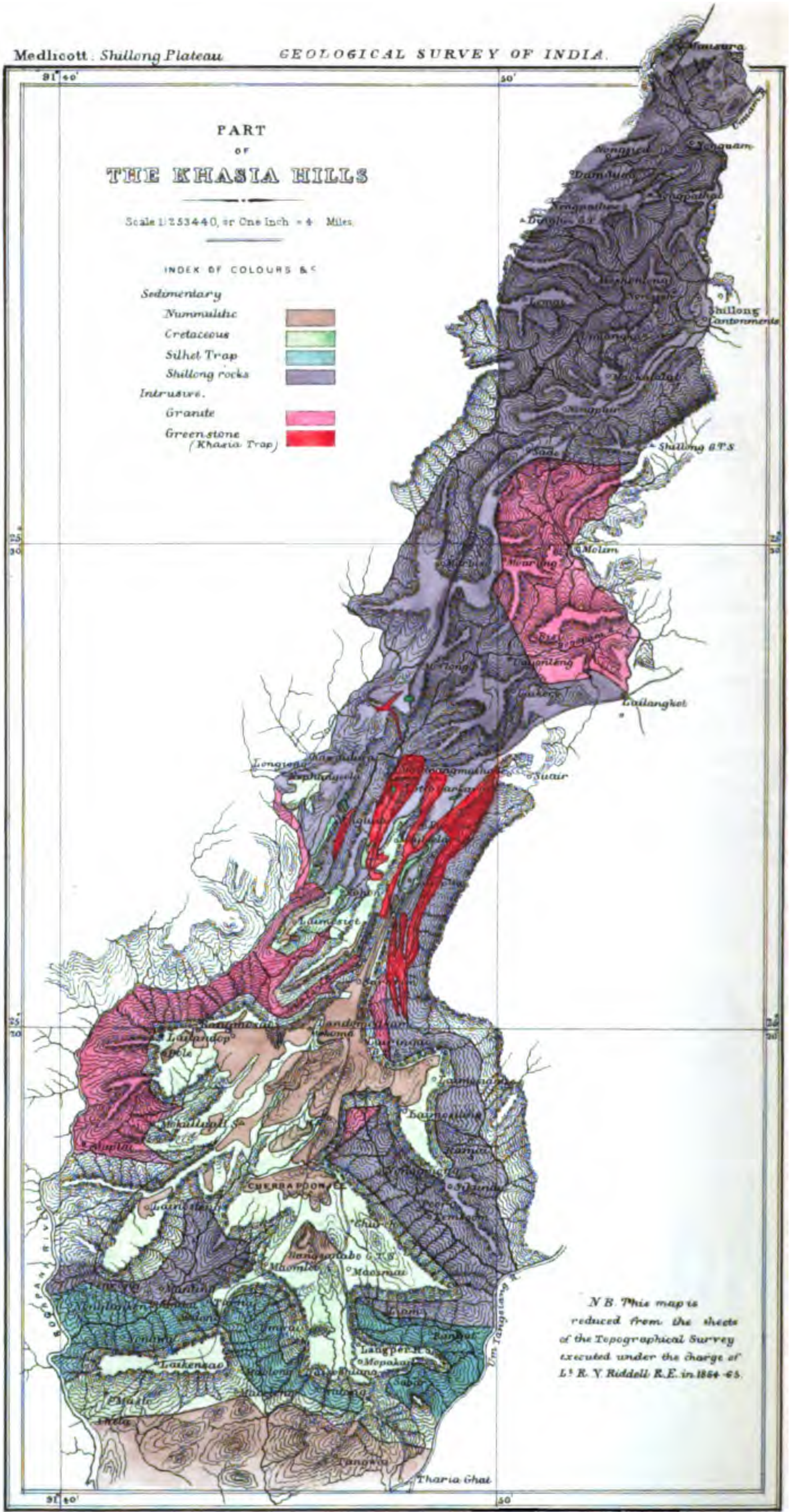
Toposi ...	...	4,80,000	3,00,000	4,70,656	6,51,543	6,81,574	...	...	...	4,42,862½	4,63,905	
Ditto ...	...	...	...	...	...	1,02,660	5,21,416	5,25,927	2,06,154	...	...	
II.—Localities in the Rajmahal Hills.												
Bankijorah	10,000	45,000	30,000	63,935	44,329	300	...	...	...	...	...	From 1861, inclusive, the out-turn of Chilgo, Gopikandur, Oormoo and Koondapahar, included in this.
Borah } Hurra } ...	...	4,20,000	7,00,000	...	...	...	...	...	...	...	...	
Burgo ...	...	6,000	...	...	...	...	...	...	...	...	...	
Chilgo ...	5,000	10,000	20,000	...	...	...	...	...	...	...	...	
Domunpur ...	...	...	2,343	...	...	...	...	...	...	...	...	
Ditto ...	...	30,000	8,000	...	...	...	...	...	...	...	...	
Ghatchowra ...	8,000	...	...	...	...	...	...	...	...	...	...	
Ghutkum ...	...	...	50,000	...	...	...	...	...	...	...	...	
Gopikandur ...	7,000	...	...	...	...	...	...	...	...	...	...	
Hurrinsingah ...	48,000	...	...	...	...	...	...	...	...	...	...	
Koondapahar ...	5,000	10,000	1,000	...	...	...	...	...	...	...	...	
Lohundiah ...	...	...	86,000	...	...	...	...	...	...	...	...	
Oormoo ...	...	26,000	30,000	...	...	...	...	...	...	...	...	
Panchbaini ...	36,000	60,000	14,000	...	...	...	...	...	...	...	...	
Simlon ...	...	...	8,600	...	...	...	...	...	...	...	...	
Sursabad ...	...	...	75,517	...	...	...	...	...	...	...	...	
Teesaphuli ...	1,00,000	1,50,000	2,10,000	...	...	...	...	...	...	...	...	

(150)

No. II,—*concluded.*

RETURN of COAL raised in INDIA *during each year from* 1858 *to* 1868 *inclusive,*—concluded.

NAME OF COLLIERY.	1858.	1859.	1860.	1861.	1862.	1863.	1864.	1865.	1866.	1867.	1868.	REMARKS.
					III.—LOCALITIES IN THE KHASIA HILLS.							
Cherra Pûnji ...	10,253	18,731	24,943	16,167	...	...	...	...	...	...	...	Closed in 1861.
Lakadong ...	12,066	13,767										
					IV.—LOCALITIES IN ASSAM.							
Borhaut ...	...	...	...	...	...	...	...	...	...	...	6,000	
Namdong ...	...	...	...	...	...	...	...	...	...	...	2,000	
Terap ...	...	...	...	...	...	...	...	...	...	...	7,000	
					V.—LOCALITIES IN SANTHALIA, &c.							
Bokaro (Hazareebaugh)	...	...	...	...	...	...	...	...	...	...	...	No returns.
Kotah ...	...	...	...	...	...	...	...	...	...	...	...	No returns.
Kurhurbali ...	4,000	1,08,182	2,75,256	2,63,705	2,75,661	25,396	...	...	...	...	...	Being reopened now.
Palamow ...	...	28,648	30,900	33,343	43,772	...	...	...	...	...	...	Small working progressing now.
					VI.—LOCALITIES IN CENTRAL PROVINCES, &c.							
Lameta Ghat ...	...	...	...	...	...	...	...	...	...	...	63,519	
Mopani ...	...	...	...	...	...	...	...	...	...	12,853	236	
Sher River ...	...	...	...	...	...	...	...	...	...	...	33,700	
Salt Range ...	...	...	...	...	...	199	9,742	27,538	14,596	710	...	
Sind (Lynyah) ...	45,300		...	...	...	...	...	...	...	...	...	



Lithogd. from a drawing supplied by Supdt. Geol. Survy. at the Survr. Genl's. Office, Calcutta, August, 1869

Geological Sketch of the SHILLONG PLATEAU *in North-Eastern Bengal, by* HENRY B. MEDLICOTT, A. M., F. G. S., *and Deputy Superintendent, Geological Survey of India.*

CONTENTS.

1. INTRODUCTION.

The extensive hill-tract in north-eastern Bengal to the south of the great valley of Assam has already been twice noticed in the Memoirs of the Geological Survey of India.* Recent orders of Government to investigate some reported coal discoveries in the western portion of those hills have given another opportunity of adding to our information upon the geology of this region. Although it presents a well defined orographical feature of no small extent, geographers have not yet assigned a name to this area as a whole; it is locally spoken of in segments by the names of the several tribes which inhabit it. To supply this want, it was proposed, in the last paper above referred to, to call this elevated tract the Shillong plateau from the name of its culminating and nearly central point, and avoiding any of the partial names now in use, as likely to lead to confusion. As a plateau, formed in great part of horizontal rocks, its position is remarkable, occupying, as it does, neutral ground in the acute angle between two great regions of special disturbance—the Himalayan on the north, and the mountain-system that separates Bengal from the great valley of the Irrawaddi on thesouth-east. The area that can be described as table-land appears on maps

* Vol. I, p. 99, and Vol. IV, p. 387.

as closely connected with these latter mountains, from which it is only separated by a system of narrow continuous valleys. The lofty Burrail ridge forms the south-eastern side of these valleys; it runs steadily from the north-east, curves round most regularly to a westerly direction, dying out in the plains near Jynteapur. The detailed study of the drainage of this region, as related to the structure, and as bearing upon the asserted conversion of transverse into longitudinal* river courses, would probably yield much instruction. The drainage of this series of longitudinal valleys is very variously effected by several streams, all more or less torrential. The Dunsíri, flowing north-eastwards into Assam, drains about one-half the total length; and seems to have thus cut off, and diverted along the line of easiest erosion, the original transverse system of drainage from the Burrail across the table-land on the north-west. On the south-west side the drainage is still transverse: the several streams, of which the Jatinga is the most important, after the confluence of their east and west tributaries in the longitudinal valleys, pass southwards by narrow tortuous gorges through the Burrail ridge. This course of the transverse drainage here, right across the ridge, forms a very puzzling feature in the investigation I have suggested.

The northern slopes of the longitudinal valleys along the base of the Burrail form the face of the table-land, and are continuous with that middle portion of it, which for the space of about fifty miles rises almost immediately from the plains of Silhet. Still further westwards the boundary of the table-land trends towards the west-north-west to Singmári on the Bramahpútra, leaving at the south-west angle of the Gáro district a width of twenty-five miles of low fringing hills: Thus the southern boundary of the table-land proper forms a pretty regular arc of a circle.

On the north the boundary of the high land is less well defined; there being broken ranges of low irregular hills stretching across Lower Assam to the Himalaya; they run into the table-land, being made of

* It need hardly be stated that these terms have reference to the orographical system of the region.

the same metamorphic series that occurs in it. The Bramahpútra is slowly enveloping these hills in its alluvium.

The length of the Shillong plateau, from Golaghat on the Dunsíri, to Singmári on the Bramahpútra, is about 250 miles. The width would average about 25 miles. The general level of the plateau ranges between 4,000 and 6,000 feet.

The only part of the Shillong plateau that has been examined in any detail is a narrow strip about its centre, in the region inhabited by the Khasias, from Cherra Púnji on the south to beyond Shillong on the north. It was here that Mr. Oldham made his observations in 1851 and 1852; it was here that I made an eight-day excursion in 1865; and it is here that I have again had an opportunity of more minute examination. It seems probable that all the rocks of the plateau are represented on this middle section.

I would briefly recall the general geological features: at the two extremities, Singmári and Golaghat, cretaceous strata rest undisturbed upon metamorphic rocks; and throughout the intermediate length, on the southern half of the plateau, the same condition obtains, sandstones of the cretaceous period lap up horizontally, more or less continuously or in outliers, upon the metamorphic rocks; which latter show an unbroken range along the northern face towards Assam. At many points large patches of nummulitic strata cap those of the cretaceous period; and on the south-east portion of the table-land, where the area of the sedimentary rocks is broadest, beds younger than the nummulitic, and possibly of middle tertiary age, are largely developed, maintaining the horizontality characteristic of the table-land area. It is, indeed, only on the strength of the stratigraphical conditions that this portion of the area can be brought under the designation of table-land; the soft massive sandstones of the younger formations present such general homogeneity of texture that they have been deeply eroded, producing a surface of steep undulations, or

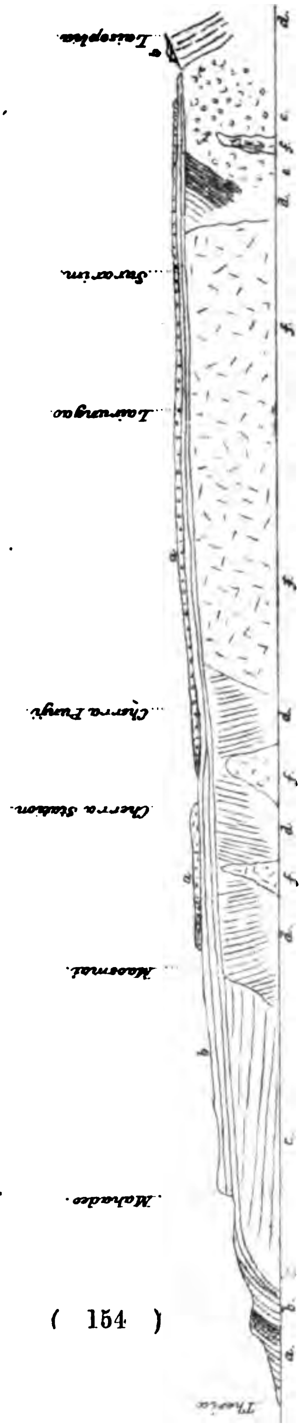


Fig. 1. General section from Theria to Laisoplia Hill, following the high ground through Cherra Púnjí.
Scale, 1: 138,720 = 2 miles to an inch.
a, Nummulitics; *b*, Cretaceous; *c*, Silhet trap; *d*, Shillong series; *e*, Khasia greenstone; *f*, Granite.

very irregular ridges, with hardly any level ground. The orographical feature that has been described along the south-eastern boundary of the plateau corresponds closely with the stratigraphical structure: the longitudinal valleys along the flanks of the Burrail ridge are on or near the axis of a great uniclinal (or semi-anticlinal) flexure, along which the rocks of the plateau are bent down into the area of disturbance. The same stratigraphical feature continues all along the south face of the plateau; but from Jynteapur westwards the ridges formed by the contorted strata are only represented in a very subordinate way, and are confined to a narrow zone along the base of the table-land scarp, which rises abruptly from the plains for a length of about fifty miles; when again low flanking hills occupy a wide space. There is evidence to show that in this westerly direction there is a gradual decrease of the phenomena of disturbance. A general section (Fig. 1) is appended, to which reference may frequently be made.

2. ALLUVIUM.

Any observations, however incomplete, that may help in discussing the question of the great fluviatile formations of the plains are worthy of record. In a nearly central position in the plains of Lower Bengal, extending in a northerly direction from Dacca for about sixty miles, there is an extensive terrace of earthy deposits known as the Madhopur jungle. It is raised some forty or fifty feet over the general level of the surrounding deltaic deposits. This ground has never been closely examined, but various conjectures have been made to account for it. Mr. Fergusson, in his description of the delta of the Ganges,* considers it to be an area of special upheaval. This view was never supported by sufficient evidence; and those acquainted with the geology of the country had long since connected this ground with similar areas elsewhere, having the same relation to the actual river deposits. Some observations I have made this year will bring this connection much nearer home. The northern extremity of the Madhopur jungle is about thirty miles distant from the base of the Gàro hills, and all round the base of these hills on the west there is a terrace of old alluvial deposits. It occurs close in to the hills, where more or less protected by the spurs; and it presents an abrupt edge overlooking the present alluvial surface. It could hardly be questioned that this ledge is a part of the same deposits as those forming the Madhopur area—all being the remnants of a much more advanced delta than the present one—and that the phenomenon which produced the change was much more general than that assigned by Mr. Fergusson.

The removal of these older deposits has been so general, and their elevation above the present surface of deposition is so considerable, that it would not be possible to bring the facts within the range of the simple process of delta-formation—of those changes which take place in the course of a delta-forming river owing to the partial distribution and

* Quar. Jour. Geol. Soc., London, Vol. XIX, p. 321, 1863.

accumulation of its deposits at any one time. These Madhopur deposits cannot be considered as belonging to the present delta, but probably (in my opinion) to one which has been extensively destroyed throughout its upper area by the action of the rivers that had formed it,* and owing to an increase in the fall of these rivers beyond the limiting angle of delta-formation, or rather of fluviatile alluvial deposition.

There is another natural agency by which it might be possible to account for features of this kind without an appeal to crust-movements. If one could imagine the very extensive destruction of the lower portion of a delta by oceanic violence, the rivers would then find a free discharge at a point so much higher up that, if the whole area of the delta had attained the limit of slope due to its farthest advance seawards, a certain amount of erosion must take place. To one who has seen a great delta, any conceivable operation of this natural agency becomes utterly inadequate for an appreciable result of the kind required: the amount of increased fall in the river course required for the production of the features now under notice would be too great to be accounted for by any destruction of the lower delta from superficial causes, such as an unusual violence of the sea.

We are thus compelled to introduce changes of level; and a little further consideration shows that there must have been depression of the lower region of that delta of which the Madhopur area is a remnant. An elevation of the upper area only of the river-basin, although it would increase the fall and thus entail the removal of previous deposits within the area affected, would cause no such destruction of the lower region of the delta, but on the contrary its rapid augmentation. An elevation having its limit near the outer margin of the delta would, by

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* The whole question of how far the "old alluvium" may or may not be a marine or estuary deposit, and therefore *raised* into its present position, is still open. It would be too tedious to discuss it here, even were I prepared to make the attempt. I assume the side upon which there seems to me a balance of evidence.

the increased fall and the cutting thereby entailed, produce features very similar to those now presented by the older alluvium, but in a far less striking manner than would result from the partial depression of the delta proper; and such a movement would not at all account for other features of the area under notice, such as the existence of the Silhet jheels: The delta of the older alluvium, although its outer margin need not perhaps have been more advanced than that of the present delta, must have been much more formed; and simple denudation, due to the cause we are now supposing, could not have reduced any part of its surface to a level so far below that of the surface of fluviatile deposition (calculated from the supposed outer margin), as is that of the Silhet jheels. The argument, indeed, cannot proceed so far; for, if the surface of the older alluvium is not now, as I have just conjectured, more elevated than the limiting plane of deposition due to the actual seaward base-line, an upheaval which brought it rapidly to that level could not cause the extensive denudation we are seeking to account for.* We are thus compelled to adopt the supposition of the depression of a large portion of the old delta; and it must have been a very extensive operation to produce the features now presented by the older alluvium—effects reaching to the upper limits of the alluvial plains, as evinced by the permanent valleys (khàdars) through those older deposits in which the great rivers flow for the upper part of their course, reversing there the conditions of delta-forming rivers.† The position of the Madhopur area in the middle of the delta is very important as giving some clue to the limits of the area of depression. The conclusion thus arrived at as to the depression of

* The assertions running through these sentences depend upon certain propositions regarding the growth of fluviatile deposits illustrated by Mr. Fergusson, and which are in some degree or other of mathematical certainty.

† This feature of the upper plains, the formation of permanent *doàbs*, might perhaps to some extent be produced by the gradual erosion of the steep torrential gorges of the great rivers within the mountain area, entailing the formation of corresponding channels through previously deposited alluvium in the plains.

a portion of the present deltaic area, especially on its eastern side, is only in confirmation of other independent evidence.

Along the south base of the Shillong plateau from east to west the process of alluvial formation, and the preponderating influence of the Bramahpùtra, are well exhibited. In Silhet, swamps and perfectly level alluvial flats stretch up to the very base of the steep rocky hills; and the rivers for a short distance have a steep fall in very shallow and variable beds over the coarse debris they have themselves brought down; they very soon, however, loose all perceptible fall, becoming *khàls*, or tortuous, anastomosing, slack-water canals—the condition of all the minor water channels in a delta. Westwards, in Mymensing, the general level of the plains rises gradually but considerably; swampy areas are rarer; there are locally the beginnings of undulation from pluvial denudation, showing that deposition has there reached its limit for some time; deposition has begun to encroach upon the river-gorges; the coarser debris scarcely reaches the open country, and rock-barriers do not occur for some distance up the gorges; the water-surface in wells in the dry weather is eighteen to twenty feet below the general level of the country. It is evident that the contrast I have described between the conditions of the surface in Silhet and in Mymensing is due to the great accumulation of detritus from the Bramahpùtra during the time when it flowed to the east of the Madhopur terrace; and it is equally evident that the recent change in the course of that river is due to the elevation thus temporarily produced in this eastern channel above that of available channels to the west of the Madhopur terrace. It is probable that its period in this western course will be of comparatively short duration; the Ganges and the great Himalayan tributaries being its competitors for that ground.

It is worthy of notice that the comparatively recent depression of the eastern area of the delta, far into Silhet and Cachar, as exhibited in the features of the alluvial deposits, is a continuation of the same phe-

nomenon as is evinced in the structure of the older formations now to be described.

3. Supra-Nummulitic deposits.

There is very little to be said as yet regarding the rocks younger than the nummulitic. In the Khasia region there is only a remnant, of them visible along the outermost spurs of the low flanking hills, where they exhibit the maximum of disturbance, being quite vertical and folded. In the absence of proper fossil evidence the distinction is at present vaguely and provisionally made upon a general difference of lithological characters. Among the younger rocks the most prominent is a thick-bedded soft greenish-gray sandstone, very like the common rock of the Sub-Himalayan series.

In the eastern portion of the plateau in North Cachar, there is a great thickness and extent of these beds still quite undisturbed; and it would seem that in the adjoining mountain region the great ridge of the Burrail, which far outtops the plateau, is principally made of these rocks.

Westwards, in the Gàro region, this series is again well exposed; but its thickness is very much less than in Cachar, and at the same time the disturbance exhibited outside the area of the plateau is much reduced in amount, and somewhat modified in form, as will be described further on. The sandstone of Nonkalong in the Habiang Gàro hills, from which Captain Godwin-Austen made a collection of fossils,* and which is within the high-level area, is probably the bottom of the supra-nummulitic series, as there seems to be a very decided denudation-unconformability between it and the underlying nummulitic limestone. The general parallelism of the groups is, however, maintained throughout.

* Among these Dr. Stoliczka recognises the genera, *Conus*, *Dolium*, *Dentalium*, *Cardita*, *Cardium*, *Tellina*, *Nucula*, *Leda*, *Cucullæa* and several others; and remarks that none of the species, so far as recognisable, appear to be identical with those known from nummulitic beds of the same district.

It is certain that formations much younger than those now mentioned, but partaking of the same phenomena of disturbance, will yet be described as occurring in these regions; at several points along the edge of the hills, beds of quite unindurated clay, sand, and gravel, with boulders have been observed, dipping at high angles towards the plains.

4. The Nummulitic Series.

Regarding the upper limits of the nummulitic series I have no more to say than can be gathered from the preceding section. As to its relation to the cretaceous series there is now something definite to be described, and an important correction to be made in the view taken in my former paper. I there left the exact horizon of demarcation still in doubt; but I stated that the nummulitic overlapped the cretaceous strata on the north. This is not the case, at least in the area that has been examined. I fell into this error by accepting the current assumption that the several local coal seams occurring so nearly on the same apparent horizon did in fact belong to the same formation. I was thus led to conclude that all the beds with the coal in the outlier at Maobelarka were nummulitic, whereas in fact they are all cretaceous;* and I then as a natural consequence found it impossible to trace the horizon of separation. It would have been difficult, when there was not time for a close consecutive examination of the strata, to avoid this error in the section of the Cherra ridge, where the only cretaceous coal that occurs is isolated at a distance from any distinctive nummulitic or cretaceous rock; the beds immediately associated with the coal in both series being on the whole very similar to each other. It was this year in the Gáro district that I first saw the cretaceous coal where it could be certainly recognised as such; and it at once occurred to me that this key would solve the difficulties of the Cherra section; as I have since proved to be the case.

* This coal had not been discovered at the time of Mr. Oldham's visit.

From the southern edge of the table-land, for eight to ten miles to the north, the strata, and with them the surface, have a steady rise. At Cherra it is about one in twenty, or nearly 3°. It is not certain that this slope has anything to say to the rapid bending down of the same beds that takes place along the line of the scarp; it may well be an original feature, a natural slope of deposition, for, as has been before described, there is a rapid thinning out of the beds in the same direction. This decrease is particularly well seen in the cretaceous group. In the nummulitic it is not so observable, as there is no covering rock on the plateau, and the group is greatly denuded. We shall see that very important changes take place in the composition of the strata, nummulitic as well as cretaceous, from south to north, suggestive of a general thinning out in this direction; but it cannot here be shown that the bottom bands of the former series, those only which occur on the plateau here, suffer any diminution of thickness.

The southernmost outlier of the nummulitic deposits on the plateau occurs just to south-west of the station of Cherra Pùnji. There are about eighty feet of limestone, capped by about the same thickness of softish sandstone. The well known Cherra coal with subordinate shales occurs at about ten feet over the limestone. The limestone is very conspicuous, forming sheer cliffs at many places round the base of the hill. At the two points, near the north and south extremities of the ridge and more than a mile apart, where I examined the actual contact with the cretaceous sandstone, there was no sign of any peculiar separating layer; the strong finely granular limestone is firmly united to the sandstone; and there are associated strings of sand and layers of sandy limestone. This junction is in fact quite similar to that of the limestone with the overlying sandstone, which, without fossil evidence, is almost demonstrably nummulitic. The feature that has been described as an erosion of the limestone prior to the deposition of the sandstone is, I rather think, a case of underground erosion subsequent to the formation

of both rocks, with consequent crushing in of the beds immediately above the excavation. The great extent to which this action has operated, and the remarkable superficial features resulting therefrom, have been fully described in previous accounts. As far as the strata extend in this region the same band of nummulitic rocks rests upon the same band of cretaceous beds. The two are quite parallel. No change or displacement seems to have affected the lower group prior to the deposition of the upper; they are conformable.*

The limestone at Cherra Pùnji is quite isolated on the cretaceous sandstone. It is at once apparent that the hills to the north of the station of about the same height as the limestone hill are formed on the prolongation of the nummulitic strata; and one is much surprised by the total absence of the striking scarp so common along the base of the southern hill. It would be possible to explain this by the peculiar process of denudation that has operated so extensively in this region—the underground removal of the limestone and the crushing down of the superincumbent sandstones; but this removal and concealment of the limestone has no doubt been greatly facilitated by the much reduced thickness of this rock to the north. Some four miles to the north, the nearest point at which I have seen a fair section of its outcrop, the band of limestone is reduced to four or five feet. I believe that this change takes place very rapidly to the north of the present limestone hill at Cherra.

* Few terms in our vocabulary need regulating more than the word conformability. There are, I doubt not, observers who would at once pronounce this junction unconformable: the limestone beds are regular and steady; the sandstone is very much the reverse; the surface of an individual bed is often very uneven; the beds are thick, irregular, and overlapping each other; there are frequently sudden rises, much steeper than the slope of the general surface, produced by local banks of the sandstone. But these features are all such as could be accounted for by the original conditions of deposition, implying no disturbance or denudation of the older group; and this is the sense I would attach to the word *conformable*. Any more geometrical definition would deprive the term of its practical signification: a total change of deposits has its own distinct signification.

Immediately under the village of Lairungao, four miles to the north of Cherra Pùnji, there is a workable seam of coal. There is about the same thickness of rock between it and the cretaceous sandstone as in the section at Cherra; and at many intermediate points along the road, on about the same horizon, thin coal and coaly shale are well exposed; so that in all respects the horizon is well defined. But below the coal at Lairungao the strata are sandstones, with subordinate shales (often carbonaceous), except at the very base where we find one strong bed of tolerably pure nummulitic limestone resting on the cretaceous sandstone. Thus at Lairungao we have the same lowest sub-division of the nummulitic series as at Cherra, and in about equal thickness, but so greatly altered in composition.

North of Lairungao there only remains this bottom band of the formation, that represented by the limestone at Cherra; but a still further change takes place—the limestone disappears altogether. At several places north of Surarim unbroken sections are obtainable, and there is no vestige of a calcareous rock. It is with some difficulty that the exact boundary can be fixed, in the absence of the limestone; although, on the whole, the nummulitic beds can be recognized by the frequent occurrence in them of carbonaceous partings, which are wanting in the upper band of the cretaceous series. About two miles north of Surarim the nummulitic beds stop out altogether near to a rapid rise of the cretaceous beds against the quartzites of the metamorphic series. There is no saying how far beyond this point the nummulitic formation may at one time have extended. Higher beds of the series may formerly have overlapped the rising ground to the north.

At a few points to the west of Lairungao the nummulitic limestone is exposed in its characteristic position. In no case is there more than a few square feet visible, so it will be well to indicate the spots: in the bed of a streamlet a quarter of a mile to east of Mokma; on the south side of valley, three quarters of a mile to south-south-west of

Mokma; and at about half a mile to south-west of Rangimasao village. The rock is exactly alike in all—a pale blue, strong, compact limestone, very locally and capriciously shaly, sandy, or granular. It is more fossiliferous than any bed I could find in the limestone at Cherra, but unfortunately it is very rarely that any but the weathered sections of shells are obtainable. It may be worthy of notice that this line of extinction of the nummulitic limestone is about coincident with the beginning of the southerly slope of the bedding. The final stopping out of this formation will be best described in connection with the cretaceous formation.

At the base of the table-land on the left bank of the river, half a mile above Theria Ghât, there is a minimum section of about 1,000 feet of nummulitic rocks as follows:—

Younger Tertiaries.	
Blank section.	
Massive coarse blue limestone, interbedded near the junction with ...	200
Clear yellowish, coarsish sandstone	100
Fine, compact or chalky, blue or pink limestone	200
Greenish and ochreous, earthy sandstone	50
Limestone	50
Yellowish sandstone	100
Limestone	200
TOTAL ...	900

There is a steady high southerly dip throughout. The two lower bands would represent those at Cherra. It is not unlikely that a little excavation would disclose a representative of the coal in the lowest sandstone. In the parallel section on the Bogapani, below Chèla, there is a coaly layer in the sandstone just over the bottom limestone. There also we find a limestone above this sandstone; but the section is not so complete as in the Theria river. Thus there is every probability that the sandstone with the coal at Cherra is truly nummulitic. There would be no proving, from this section, that those upper bands of limestone of the southern locality did not once exist on the plateau; but, on the whole,

the presumption is in favor of a great thickening of the series to the south. The intimate association of the sandstone with the limestone in the section at Theria Ghât, and the wholesale substitution of one for the other between Cherra and Lairungao, would lead one to anticipate much variation in the composition of contiguous sections.

There are equally important modifications to be noted in the nummulitic strata along the strike of the formation. For some distance to east and west on the plateau the sections are very similar to that on the Cherra ridge. But all the details of the section are much altered in the North Cachar district where I crossed the plateau in 1865. The cretaceous beds show at the northern edge at a low level resting on the gneiss; and I crossed from the cretaceous to the younger Tertiary rocks (which there form the highest ground) without detecting any characteristic nummulitic beds. I was marching by long stages, and the rocks are greatly concealed, but if the limestone were present even to the same extent as on the plateau at Cherra, I could scarcely have failed to notice it. It may be that there too the formation thins out to the north, and that the present outcrop is on this attenuated portion.

Regarding the western region our information is much less vague. In the Gàro district the high plateau is almost entirely formed of crystalline rocks, I believe of the gneiss. All the upper part of the scarp is of this rock, against the base of which the unaltered sedimentary beds turn up or abut. We have no knowledge as yet of any outliers of the younger strata that may exist here on the higher ground. At Tura, the only high point I was able to ascend to, there is no vestige of a capping rock. I can only speak of what is seen in the low flanking hills where the whole sedimentary series is well exposed. On the Sumésari river, sixty miles to the west of Theria, the nummulitic limestone rests, as elsewhere, directly and conformably upon the cretaceous sandstone. There is not more than about forty feet of it; and it is the only band that occurs. But it is not in respect of thickness that

the greatest change is observable. In the Khasia region the nummulitic strata consisted of clear sandstones and limestones; here an earthy element preponderates. The limestone is in thin layers, often lenticular, nodular, earthy, and ochreous, and with shaly partings. There is a thick bed of fine yellowish sandstone close above the limestone, but it is overlaid by a considerable thickness of shaly clays, some pure and plastic. I noticed no signs of a carbonaceous deposit. In the Cherra district it would scarcely be possible to ascertain accurately the upper limit of the nummulitic formation, the beds above the strong limestone are so extensively denuded. On the Sumésari the investigation might be undertaken, but the special object of my research in visiting this region did not admit of my delaying for this purpose. There is a strong band of sandstone overlying the clays, and of the same type as that associated with the limestone; and in the section of the actual river banks, there is a blank before the peculiar rock of the upper tertiaries makes its appearance, so that, on the whole, there may be a considerable thickness of true nummulitic strata; at all events the alteration observed in the calcareous and arenaceous deposits is in itself remarkable.

Forty miles further to the west, on the Kàlu river, at the extremity of the hill region, the same change in the character of the nummulitic deposits is still further developed, and the contrast with the cretaceous rocks is very great. I could only observe the limestone in one spot: at Domalgiri the massive clear cretaceous sandstone is well exposed in the river, which flows from the north across the strike; the southern face of the sandstone ridge is strewn with blocks of earthy rusty concretionary nummulitic limestone, evidently derived from a bed on the spot; and there can be very little of it, for the stiff overlying clays are in force immediately above; there seems to be little or no sandstone.*

* This limestone reminded me strongly of the nummulitic limestone of Subathu in the North-West Himalayas.

The area described by Captain Godwin-Austen* in the neighbourhood of the Umblai, the boundary of the Khasia and Gàro districts, seems in every respect to be a most interesting one. It corresponds with a remarkable depression extending right across the plateau; and there seems to be a local development of some groups of the sedimentary series. Some striking instances of irregularity in the nummulitic deposits are noticed: in one section, within a short distance, a distinctive top run of limestone passes on to the cretaceous sandstone, overlapping some 200 feet of lower limestone beds.

Upon the few nummulitic fossils I was able to procure, Dr. Stoliczka has given the following note: "Lairungao, the northernmost limit of the limestone;—a bluish gray compact limestone, some of it consisting entirely of little fragments of various shells, in a calcareous cement. *Operculina canalifera*, D'Arch., and *Nummulites Lamarcki*, D'Arch., are very common; besides these—fragments of a *Trochocyathus; Stylocœnia Vicaryi*, Haime; *Echinolampas spheroidalis*, D'Arch., a small *Cardita; Pecten; Natica Rouaulti*, D'Arch; *Keilostoma marginatum*, Lam.; a *Ziziphinus;* the small *Cerithium Hookeri*, D'Arch., casts of a larger *Natica, Cerithium, Terebellum*, etc. Cherra Pùnji—limestone like the last, portions consisting almost entirely of small specimens of *Op. canalifera; Num. Lucasana* and *Num. Ramondi*, both the last species very small; there are also species of *Echinoids*, fragments of *Oysters*, and *Pecten, Cardium Salteri*, D'Arch.; and various fragments of *Natica, Cerithium, Turritella* and others. Those portions of the limestone which consist chiefly of shell fragments generally do not contain many Nummulites; these occur gregarious in separate masses.

"The earthy limestone of Ryak on the Sumésari in the Gàro district is almost made up of a mass of *Num. granulosa*, D'Arch., in various stages of growth."

* Jour. Asiat. Soc., Bengal, Vol. 38, Pt. 2, p. 1, 1869.

5. The Cretaceous Series.

It would scarcely be possible to make anything like an exact lithologico-stratigraphical scale of the cretaceous deposits at Cherra Pùnji. Small as is the length of the section and considerable as is the total thickness, there is no character constant in, or to, any one horizon. The series may be said to be sandy throughout; but the varieties are very numerous, and their distribution is most inconstant. The nature of these deposits and their unassorted condition would seem to be owing to the proximity of the area of erosion from which they were derived. The thickness changes from 1,200 feet at the scarp of the plateau to 670 feet under the middle of the station of Cherra; at about one mile further north, it is reduced to 560; at a point ten miles from the scarp, where the nummulitic beds make their last appearance, there is only about 100 feet of cretaceous sandstone. This very rapid reduction is an original feature, in no way aided by denudation. Still we are far from having ascertained the limit of extension of the formation: for many miles to the north outlying patches of the cretaceous sandstone are found; not indeed as capping to the high points, but rather on the sides of existing depressions; showing that the pre-cretaceous surface of the metamorphic area had to some extent the same contour as the present one. Beneath the strata of the main area the surface of the metamorphic rocks seems remarkably even.

The difficulty that has been felt in assigning a horizon of separation between the nummulitic and cretaceous deposits at Cherra Pùnji is attributable to their general similarity of composition and of arrangement, and to the fact that between the two known fossilliferous rocks in each there is a band of some 200 feet thickness, in which no fossils have been found save vague stem-like non-carbonaceous vegetable impressions, and which might belong to either formation. There is indeed a superficial feature which markedly suggests the association of this band with the lower series: this is the rock which so generally forms a

terrace or ledge along the southern zone of the plateau (such as the flat upon which the station of Cherra Pùnji is built); so that the eye can with the greatest nicety follow the horizon of the upper surface of this sandstone all round the edge of the deep valleys. It is, however, evident that this feature may be entirely due to the presence of so easily soluble a rock as the limestone immediately overlying this sandstone, and not to any peculiarity in the sandstone which is often undistinguishable from the rock above the limestone. It has been shown that the Cherra flat has been in great part, probably altogether, formed by the underground dissolution of this limestone, and the subsequent removal of the crushed debris of the overlying beds; and in fact, where the limestone is absent the ledge I speak of also disappears; and we find the nummulitic beds in the same sheer cliff with the cretaceous, as about Surarim. It is in such cases that the difficulty of assigning any distinguishing character between the two sandstones is fully experienced.

If the upper surface of this Cherra band suggests, at least superficially, its separation from the nummulitic group, there are local relations which would as strongly suggest a separation from the mass of the cretaceous deposits: The only sharply defined line of contrasting deposits that I could find in the series below the nummulitic limestone was at the base of this Cherra band. In the angle of the cliffs under Maosmai, about 200 feet from the top, the bottom bed of the Cherra band, a massive coarse felspathic sandstone, rests directly upon a fine sandy limestone containing *bryozoa*. The contrast of the deposits is very marked; and in looking from the east at the north and south cliff there is an appearance of pseudo-unconformability along the line of this junction: in the rough strata of the upper band, there is an arrangement as of overlapping each other from the north, as it might be in a diluvial deposit accumulated from that quarter, and in the underlying strata, there is an arrangement as of overlapping from the south, as if so banked at the edge of a water basin—the plane of junction overcutting

the beds of the upper band, and undercutting those of the lower, as in the figure:

Fig. 2. Junction of Cherra and Lángpar bands, Maosmai cliffs.

Elsewhere this lower horizon of the Cherra sandstone is by no means so well marked. In the angle of the cliffs under Cherra village on the north (the only section I know of in which every bed of the series can be got at) the distinctive composition of the Cherra band from that below it is very decided, but there is only an approximate position assignable above or below which the fine calcareous sandstone of the lower band or the coarse sandstone and mottled sandy clays of the upper do not pass. This vagueness may be due to the accident that the more characteristic rocks of the two bands do not here happen to occur at the contact, as in the other section; but it also suggests a transitional and uninterrupted formation for the whole series—the view I am inclined to adopt. The lumpy, mottled, sandy clays or earthy sandstones, so well seen in this locality, are characteristic of the lower part of the Cherra band on very many sections; but they are sometimes unrepresented.

As far as it goes this top sub-group of the cretaceous series must of course be recognized; but its range is not extensive. It does not seem to be represented in the section at Theria Ghât. In the parallel section on the Bogapani at Chèla, there is about 40 feet of fine hard pale sandstone in the position of the Cherra band, so far as that it immediately underlies the bottom nummulitic limestone.

The position of the Cherra band in the northern sections establishes its connection with the cretaceous series. While all the peculiar rocks of the southern scarp thin out and disappear northwards, the Cherra

band continues well represented, and finally it seems to coalesce and identify itself with the bottom rock of the whole series. This union is complete about Surarim; and the single band continues northward over, or rather through gaps in, a barrier of metamorphic quartzites to Maobelarka, a mile and a half beyond the disappearance of the nummulitic beds, where it contains a seam of coal four feet in thickness. Such is at least the *primâ facie* view of the section, subject of course to correction from palæontological evidence. It is perhaps presumable that such correction will be made, since this band, here of one to two hundred feet in thickness, seems actually to represent a series ten times as thick at a distance of ten miles to the south. A description of the bottom band will make the case more intelligible, and will suggest an argument for the association of all the strata at Maobelarka, as belonging to the upper horizon of the series, equivalent to the Cherra band. An argument for the separation of this bottom band as a group, which has been throughout synchronous and a truly bottom group whatever member of the series it be found associated with, will be mentioned afterwards.

The bottom rock of the cretaceous series has one character that is nearly constant within the region of the plateau—that of being a coarse conglomerate. The large debris is almost entirely derived from the neighbouring quartzites of the Shillong series; it is generally sub-angular. From the high level on the shoulders of Laisoplia hill north of Surarim to the low level 1,000 feet under the terrace of Cherra Pùnji on the south, this rock forms one continuous band, varying locally from twenty to one hundred feet in thickness. Although thus forming one band, having the same relative position to the overlying portions of the same series, it physically belongs to every horizon; and it is at least possible that geologically it does so also—that it would be erroneous to give it a name as a sub-group (as being the bottom rock throughout), implying a date of formation prior to that of all the other rocks of the series; as for instance, that the conglomerate at Surarim is older

than the glauconite-sandstone at a much lower level under Cherra. There are lithological and stratigraphical local facts which would support such a partition of the bottom conglomerate, and the association of the several portions with the beds contiguous to each: the sandstone matrix of the conglomerate varies with the nature of the adjoining sandstones—in the southern region it is often coarse and granitic, in the middle region it is often fine grained and purely siliceous, and to the north it has all the characters of the beds of the Cherra band. Another point in favor of this view is that in all positions there is more or less of transition, by interstratification, between the conglomerate and the sandstone immediately overlying. Both of the characters here noticed may be well seen in the section below Cherra village on the north, where the fine grained and calcareous band (the second highest of the sub-divisions that are recognisable hereabouts) passes into the conglomerate.

The only special fact I observed that would suggest the entire independence of the bottom conglomerate and of its immediate coverings, and therefore its most distinct separation from the Cherra band where in the northern sections, they appear to coalesce, was the very frequent symptoms of carbonaceous deposits in the bottom rock. Along the Liam glen south of Cherra there occurs a fine tough sandstone just over the conglomerate full of impressions of gnarled wood; these are generally mere impressions, but also often with a coating of coal, and associated with threads of coal. The very same thing occurs under Mamluh; and here I found in the same position, under the cliffs to west of the village, a bed of carbonaceous shale full of obscure plant remains. It is exactly on the same horizon, overlying the conglomerate, that the cretaceous coal occurs at Maobelarka. I have no sufficient observations as to whether this character is constant between these two positions; but even if it were so, it would after all be very incomplete evidence for the unity of the band: were it possible to discriminate the plants in the two

localities they might furnish the most complete confirmation for the distribution of the conglomeritic deposit as suggested in the preceding paragraph. In the Cherra band itself I have not anywhere seen carbonaceous remains; but in the calcareous, and undoubtedly marine beds next below it specks and fragments of carbonized vegetable matter are very common. This question of the range of the carbonaceous deposits may be successfully investigated in the region of the Umblai, some thirty miles to westwards, where according to the observations of Captain Godwin-Austen, who is conducting the topographical survey of the hill region, they have a much greater development, both horizontal and vertical.

North of Cherra Pùnji the final rapid thinning out and isolation of the cretaceous deposits and the total disappearance of the nummulitic strata are local features connected, through denudation, with the distribution of the supporting rocks. There is a steady line of junction, running north-north-west from Surarim, of coarse granite on the west with the Shillong series on the east. The former was more decomposable and more denuded than the latter. The distribution of the cretaceous strata within the area of the Shillong series is connected with similar causes: these newer strata occur in pre-cretaceous valleys in the run of the schists and of the eruptive rock, the higher ground being formed of the hard quartzites of the same metamorphic series. These features are well exposed on the three ridges of Laisoplia, Maobelarka, and Maokaleng. On the latter the whole series is stopped out near the village of Kokon; and the best view-sections are there obtainable, on the sides of the steep gorge to the east of the village, of the banking up of the strong conglomerates and sandstones against the rise of the quartzites. The Cherra band is continuously traceable from the south, and at many points passes up over the quartzites, quite overlapping the massive conglomerates. The little coal basin of Maobelarka is not strictly an outlier; there is a narrow neck of the conglomerate and the sandstone connecting it

with the main area. On the Laisoplia ridge there is the best section of the sudden termination of the nummulitic group, and of the puzzling association of the Cherra sandstone with the bottom conglomerate: at the contraction of the narrow ridge from Surarim, at the south-west angle of Laisoplia hill, the quartzose conglomerate of the Shillong series, schistose and vertical, is weathered out for a few square yards, capped by the cretaceous conglomerate; the plane of junction is several feet higher than even the nummulitic beds at 120 yards to the south; on the south side of the saddle, which is about 70 yards long, the cretaceous sandstones of the Cherra band form a little scarp, and pass continuously at a lower level round the west flank of Laisoplia hill; at about fifty yards to the south of this first little scarp there is another formed of the nummulitic beds, which are traceable continuously from Lairungao, and are also distinguishable by the frequent carbonaceous partings in them, while there are none in the Cherra band. The cretaceous conglomerate seems to cover the surface of the metamorphics, thus often occurring at a higher level than the beds I suppose to represent the Cherra sandstone. The nature of the junction of the cretaceous conglomerate with that of the Shillong series is admirably exposed on the Jawai road at this point of Laisoplia hill: there is no clean-swept surface of contact; it is difficult to say within a foot where one conglomerate ends and the other begins, although the strata in the two are at right angles to each other.

Nothing could be more natural in making a cursory survey of this locality in passing from Surarim to Maobelarka than to set down the coal at the latter place as belonging to the nummulitic formation, in which coal or carbonaceous debris is so constantly observable along the road the whole way from Cherra to within a mile of Maobelarka. Even if the stoppage of these beds on the south side of the barrier had been detected, it might easily be supposed that the nummulitic deposits came in again on the north side. By tracing the sandstone carefully

along the sides of the valley it becomes apparent that the sandstone overlying the coal at Maobelarka represents the Cherra band. But if this should be considered inconclusively proved, we have in the character of the coal itself a strong confirmation of the position—it is very different from all the nummulitic coal. The latter has constantly very much the aspect of ordinary bituminous coal—the cuboidal structure and the half-stony sound when struck. The Maobelarka coal is compact, splintery, with smooth conchoidal fracture, and a woody sound; a fine lamination is traceable, and there is commonly an irregularly prismoidal structure across the bedding. It has the further peculiarity of containing numerous specks and small nests of fossil resin. These characters would not of themselves be conclusive as to the non-nummulitic age of this coal, even though in strong contrast with the other coals of this formation; but they become so when they correspond exactly with the characters of the undoubted cretaceous coal of the Gàro district, as I found to be the case.

The extent of the deposit at Maobelarka is very limited. It shows on both sides of a small valley cut out of the sandstone on the eastern side of the narrow ridge. It is only on the southern outcrop that it has been opened to any extent; the section consists of—

	Feet.
Sandstone	
Carbonaceous Shale	1
Poor *Coal*	1 to 2
Shale	2
Close-grained batt	1
Coal	3 to 4
	8 to 10

At the other outcrop, forty yards off, these layers seem still fairly represented; but at fifty yards to the north-west a rib of quartzite weathers out along the crest of the ridge, and probably continues through the sandstone to the west of, and at a higher level, than the coal, stopping it out completely; for in the cliff on the west side of the ridge and not

more than 100 yards from the coal there is not a vestige of this to be found. The extension to the north must be equally limited, for within a short distance the Shillong series occupies the whole ridge. It does not seem either to reach far to the south, for it has not been discovered at many points where its horizon is exposed. The great abundance of pyrites is a serious drawback to this coal.

The bottom rock as characterised by coarse conglomerate is restricted to the region of the plateau, and approximately to where it rests upon the crystalline and metamorphic series. Within this area I only know of one exception to this rule: on the path descending to the village of Máplai in the valley of the Bogapani, the only strong band of coarse conglomerate occurs well above the base of the cretaceous series; and here it has the exceptional character that all the large debris is thoroughly water-worn. It is underlaid by some 200 feet of coarse massive sandstone. In all the sections to the south of the main scarp, and where the stratified trap is the supporting rock there is little or no vestige of conglomerate. The feature formed by the bottom rock here, at the base of the range, is also remarkably constant for a considerable distance. All the large rivers cut a deep narrow gap through a coarse sandstone more or less felspathic and ochreous; it is over 200 feet thick without a single continuous line of stratification; and has a high southerly dip. In the section on the Theria river there is a considerable blank before the underlying trap appears; but in the Bogapani, and in the Jadùkàtà (Umblai), the feature is exactly similar to that at Theria, and the actual contact of the massive sandstone with the trap is seen, without any conglomerate. This massive sandstone is continuous with that which overlies, and for a short space interstratifies with, the conglomerate at the higher levels; and the base of it may be supposed contemporary with the nearest conglomerate.

In the Jadùkàtà, or Umblai, a little above its debouchure into the plains near Laour, I found a fossiliferous band in a position that I

think must be near the very base of this bottom sandstone: just above the short and narrow gorge by which the river cuts across the massive sandstone it takes a sharp turn from the west, and soon again makes a wide sweep from the north-west. This wide bend of the river takes place against cliffs of the sandstone, and there is still a remnant of this rock on the inner side of the curve on the left bank, and here the fossil bed occurs at the low-water mark. Just above this bend the trap shows again on both banks forming sheer cliffs of 100 to 200 feet in height. Unless some undetected dislocation exists, this fossil bed must be close to the very base of the series. It is a friable rusty sandstone, and is the lowest bed, except the coaly layers, in which I found fossils; there are *Brachiopods*, *Echini*, and very numerous pieces of large *Inocerami*. In connection with the foregoing discussion regarding the true equivalence of the bottom rock throughout the whole area it is very interesting to observe that fragments of fossil resin are freely scattered among the marine fossils in this bed; and are probably derived from the same source as that found in the coal of the bottom beds at the higher level.

Over a portion of the cretaceous area on the plateau there are two recognisable sub-divisions of the series between the Cherra band and the bottom rock. Immediately below the former, and sometimes, as we have seen, with a sharply defined boundary, there is a group the characteristic rock of which is a very fine pale sandstone with very numerous scattered small broken fragments of plants, generally coated with dark brown or black. Everywhere with this sandstone a calcareous ingredient is associated, but in a strangely capricious manner: of two closely adjoining sections one may be strongly calcareous throughout and the other almost quite free from any such admixture. This is the case on two of the paths from Cherra Station down to Nongpriong. Generally the lime is accumulated in discontinuous layers, thick or thin, forming calcareous sandstone and every degree of sandy limestone. In the

coarser varieties of the former *Bryozoa* are found, and in the purer layers of limestone the weathered sections of shells, mostly of small turrited gasteropods are common. This band is well seen at many points of the cliffs, south of the station, where it is not more than 200 feet thick; again in the cliffs and river courses north-west of Mamluh, where it is somewhat thicker. In the cliffs at the head of the Nongpriong valley this band (or at least strata partaking in its lithological characters) occupies the whole section from the Cherra beds down to the conglomerate; and it must be some 500 feet thick. From here it must thin out rapidly to the north: I could not identify it in any of the sections beyond Lairungao. Thus this, the most calcareous band of the cretaceous series, disappears on about the same line as the nummulitic limestone. If a name were needed, these beds might be called the Làngpar band, from the spur south of Maosmai, which is mostly composed of them, although there is here still a capping of the Cherra band.

The remaining sub-division, like the preceding one, seems to have a limited north and south range. Its most general lithological character is the presence of glauconite. Under the station of Cherra this character seems confined to the upper portion of the band, there being a considerable thickness of purely siliceous sandstone below it; or it may be that these should be grouped with the massive bottom sandstone of Theria. South of Maosmai in the region of the Mahadeo terrace, the glauconite band is largely developed, often forming strong beds of dark green sand. In it too there is a good deal of disseminated carbonate of lime, and it contains much earthy matter, in thick beds with exfoliating spheroidal weathering. This band is important as being the most fossiliferous; this is the case on the path below Mamluh; and on the same horizon above Mahadeo, in the stream under Laisophlang. This band might conveniently take the name of Mahadeo. It is probably in part represented in the great bottom sandstone of the section at the base of the scarp.

From what has already been said it will have been expected that the sub-divisions of the cretaceous strata on the plateau will not answer for those seen in the low ground to the south of the axis of flexure. In the three sections already noticed in the latter position, in the Theria river, the Bogapani, and the Jadùkàtà (comprising a distance of more than thirty miles) the identity of the great bottom sandstone has been noticed. In the first locality there is about a quarter of a mile between this sandstone and the bottom nummulitic limestone; it is only for about forty yards in the middle of this space that rock is exposed—dark and pale blue shales, locally nodular and calcareous, ferruginous and concretionary, with some layers of flaky earthy limestone and of fine hard earthy sandstone. They probably represent portions of the Làngpar and Mahadeo bands; and exhibit the completion of the tendency towards the substitution of earthy for arenaceous deposits. In the Bogapani there is about the same thickness between the sandstone and the limestone; and here it might be possible to make out a complete list of the intervening rocks. With the exception of the forty feet of fine sandstone immediately under the nummulitic limestone, and which may belong to the Cherra or to the Làngpar band, all the beds seem to be of shales and limestones like those at Theria. On the Jadùkàtà all the beds above the sandstone have been denuded away for some distance from the river; suggesting the presence of soft rocks. Thus in the southern sections one would only recognise, in a cursory survey such as mine has been, two divisions —a massive sandstone at the base, succeeded by shales with subordinate limestone.

To the west of the Jadùkàtà (or Umblai) I have not seen the cretaceous rocks within a distance of more than thirty miles, as they appear on the Suméсari, ten miles from the plains of Mymensing. Although so far from the alluvial flats the elevation is but little higher than in the river at Theria, yet all the features are much changed.

The great secondary trap formation which underlies the cretaceous series to the east does not appear here at all, though it may be presumed to underlie at no great distance; and the lower rocks in contact with the cretaceous seem to belong to the older gneiss, not to the newer metamorphics of the Shillong series, or to the granite associated with this series. There is but one group of cretaceous strata here; some 500 to 600 feet of strong-bedded, coarsish, pale yellowish sandstones with subordinate carbonaceous shales and coal. The upper beds of the Cherra section do not seem to be represented. These newer sedimentaries rest against, rather than upon, the crystallines; and they have undergone a considerable amount of contortion, as appears to be always more or less the case in the strata at the base of the high plateau. The nature of the disturbance of the strata seems still to indicate considerable relative displacement of level—either the elevation of the metamorphic area or the depression of the newer rocks, or both. This has not taken place by a fault along the surface of junction, nor yet by so regular a semi-anticlinal bend as in Silhet. The plane of contact is well seen in the bank of the Sumésari just north of Seju; it underlies at 80° to the south-south-west, but it is thus parallel to the dip of the sandstone, and the bed next the gneiss is a true bottom bed containing blocks of the crystallines against which it rests in its original relative position. The surface of the crystallines seems to have bent up or down with the sandstones.

In the region of the Kàlu river, at the west extremity of the hills, the only cretaceous rocks seen are exactly of the same description as those on the Sumésari; the only difference being that they have undergone scarcely any disturbance of contortion; the sandstones are seen lapping up over a steep surface of the gneiss on the flanks of Tùra and Harigàon Hills. In the lower hills touching the Bramahputra at Singmàri, the gneiss weathers out here and there from under a covering of the sandstones; still this gneiss only occurs on the prolongation of

that forming the plateau. There are no means of fixing the extent of this overlap of the cretaceous beds here, as there is no higher ground to the north; but all the outcrops in that direction are of crystalline rocks.

In the extreme east, on the Kopili and the Nàmbà, the general conditions are like those at Singmàri—the cretaceous beds rest upon the older gneiss at a low level. On the Nàmbà (near Golaghat) the supposed cretaceous rocks are limestone and calcareous sandstone. On the Kopili at Panimao the rocks resting on the gneiss are fine pure sandstones, slightly undulating, though scarcely more than might be due to their position on an uneven surface of the crystallines. A good deal of hydrometamorphism has taken place near the surface of contact, the sandstone becoming a quartzite. It may be doubted if these beds are cretaceous. The friable, rusty, fossiliferous sandstone, of quite the same character as the Cherra rocks, and that has been recognized as cretaceous, appears at a short distance to the south of Panimao.

Dr. Stoliczka has furnished me with the following note upon the fossils from these cretaceous rocks:—

"The highest fossiliferous band, about 200 feet below the edge of cliff at Maosmai—a coarse sandy limestone with small fragments of pale pinkish compact limestone contains some little Pelecypoda, a *Cellepora,* and species of Echinoderms. A finer grained variety of the rock is principally made up of an *Astrocœnia* allied to *A. decaphylla,* M. Edw., from the Turon beds.

"From about the middle of the series, above Mahadeo in the bed of a stream under Laisophlàng, in a soft, ochreous glauconitic sandstone: a small *Nautilus,* probably *N. elegans;* fragments of a *Nautilus* with a central siphon; *Ammonites planulatus,* Sow.; *Am. dispar,* d'Orb.; *Am. Orbigyanus,* Geinitz; fragments closely allied to *Am. pacificus,* Stol., from S. India; *Anicoceras indicum,* Forbes; *Anis. sub-compressum,* Forbes; a *Baculites,* compressed laterally more than *B. vagina; Alaria papilionacea,* Goldf.; *Rostellaria (Calyptrophorus?) palliata,* Forbes; *Gosavia*

indica, Stol.; *Cerithium inauguratum*, Stol.; *Tritonidea Requieniana*, d'Orb. (two casts); *Hemifusus cinctus*, Forbes (one); a *Phasianella; Turritella; Euspira; Dentalium;* a *Janira*, close to *J. Fleuriausiana*, d'Orb. (one fragment); *Exogyra Matheroniana*, d'Orb., one small specimen; *Spondilus striatus*, Lam.; *Modiola typica*, Forb.; *Cardita orbicularis*, Forb.; *Cardium*; one small specimen of *Terebratula*, most likely *T. carnea*; *Turbinolia; Hemiaster; Holaster* and *Brissus*, with some others, not fit for specific determination. The facies of this group rather resembles that of the Ootatoor beds of Southern India.

"From about the same horizon under Mámluh a *Conoclypus*, not unlike *C. ovatus* of d'Orbigny, from the Craie chloritée.

"From the well known fossil locality about two miles from Theria ghat, on the fourth cross-cut taken by the Khasia path between the zigzags of the made road, or the first below the Devil's Bridge, the most characteristic fossils are *Nautilus lævigatus*, d'Orb., rare; *Baculites vagina*, Forbes, common; *Cypræa globulosa* and *pilulosa*, Stol.; *Rostellaria palliata*, Forbes; *Alaria tegulata*, Stol.; *Alaria glandina*, Stol.; *Lyria crassicostata*, Stol.; *Volutilithes septemcostata*, Forbes; *Tritonidea Requieniana*, d'Orb.; *Lathirus Reussii*, Stol.; *Pseudoliva subcostata*, Stol.; *Turritella Pondicherriensis*, Forbes; *Turr. multistriata*, Rss.; *Mitreola cytharina*, Forbes; *Euspira lirata*, Sow; *Gyrodes pansus*, Stol.; *Gibbula granulosa*, Stol.; *Nerita divaricata*, d'Orb.; *Euptycha larvata*, Stol.; *Actæon curculio*, Forbes, *Pecten septemplicatus*, Nils.; *Janira quadricostata*, Sow.; *Gryphæa vesicularis*, Lam.; *Spondylus striatus*, Lam.; *Pecten*, closely allied to *P. rugosus*, Dixon; fragments of an *Inoceramus*, etc.; *Rhynchonella compressa*, d'Orb.; *Terebratula*, two species, probably *T. biplicata* and *carnea*. *Ananchytes* and *Bryssus*, several species of both occur, but seem to be distinct from any as yet known.

"Nearly all the fossils above quoted occur also in the Arrialoor beds of the South-Indian cretaceous series; but there are a number of

species in the Theria beds which appear to be peculiar to the locality, and most of which are new."

The exact horizon of this Theria bed is not easily determinable, the ground being much covered and the strata disturbed; I should say it is decidedly nearer to the base of the series than the Laisophlang bed, a conjecture that is apparently opposed to the fossil evidence, the Ootatoor group being lower than the Arrialoor group in Southern India. It is certain, however, that the Theria locality was farther from the cretaceous coast line than the present outcrop at Laisophlang; and it may be subject for consideration how far the very decided difference in fossil contents may be attributed to this circumstance.

6. The Silhet Trap.

After noticing separately the several groups of the newer sedimentary rocks—which, however great their entire range in geological time, exhibit such very marked stratigraphical affinities and regularity of sequence, and which are here separated from the next older sedimentary rocks (those of the Shillong series) by such a vast hiatus in the geological record,—it would be appropriate to attempt some general sketch of the history of this region as indicated in the mode of formation and in the present condition of those deposits. But there is another great formation to be described, which though distinguished most completely from the overlying cretaceous deposits, seems to have some structural connection with this later history, and to be completely cut off from the next preceding period of which any positive record remains. This nearly isolated formation is the stratified trap so extensively exposed along the south base of the Khasia hills.

In my former paper* I showed that all the igneous rocks of the Khasia hills were of precretaceous age. I further called marked attention to the great lithological difference between the dense amorphous greenstone of the interior and the stratified trap at the south base of

* Mem. Geol. Surv., India, Vol. IV, page 418.

the hills. The total distinctness of the two was thus strongly implied, but not insisted upon or even asserted because the proofs were not present. I can now bring forward these proofs. They tend to show that the greenstone of the interior is older even than the granite, while the eruptive rock along the outer zone is comparatively but of yesterday.

As it will be convenient to have a name for this formation, I would propose to call it the Silhet trap, rather than by any name connected with the Shillong plateau; for though it extends some little way up the valleys, and shows nowhere in the alluvial plains, being, indeed, constantly separated from them by the whole thickness of the later sedimentary rocks by which it has been covered over, still its affinities are altogether with the area of disturbance. Nothing can be said as to its age beyond that it is very decidedly precretaceous, the strata of this period resting unconformably upon it, and no intertrappean deposits, nor any infratrappean younger than the metamorphics, having as yet been discovered. It might be conjectured to be of the same age as the trap of Rajmahal, which is considered to be jurassic, and which is its nearest neighbour on the west, at about 200 miles distance; but of this connection there is as yet no evidence.

There are excellent sections of the Silhet trap in the three large streams already mentioned. On the beautiful deep-water-reach of the Umblai below Rilung this rock forms cliffs of 200 feet high rising clear from the water, and displaying well the rough stratification of the trap-flows; this is also well seen in the Theria river below the confluence of the Rangat stream. On the Bogapani there is the best contact-section with the cretaceous sandstone. The belt of trap, within the distance of 40 miles where it has been observed, preserves a very constant width of two to three miles; between the very steady line on the south along the base of the sandstones and its less regular boundary with the crystalline rocks on the north. The general but

decided unconformability with the cretaceous formation has been best seen in the section of the Theria river. It is very perceptible above the river on the east, viewed from the cliffs south of Cherra Púnji: the southerly fall of the sandstones becomes more marked from a point above the north boundary of the trap, in the angle of the cliffs above Soktia; and the axis of the great flexure would run inside the south boundary of the trap; still in the middle of the zone of trap a northerly inclination of the flows is very apparent. The same is better observed in the bed of the river itself: The separate trap-flows are well weathered out and they have a northerly dip of 10° to 15°. It is only in the middle of the belt of trap that this arrangement is discernible. For some distance near either boundary the trap is quite amorphous; but this is, apparently, due to obliteration of the structure by crushing in the neighbourhood of the harder rocks, for the composition of the trap, at least near the southern boundary, is on the whole the same as elsewhere, but the different varieties,—earthy, amygdaloidal, and compact—seem all jumbled up together. It is, perhaps, possible that the disturbance noticed in the Silhet trap may have been produced at the same time and by the same causes as the great disturbance of the overlying sedimentary series; and of course this is partly the case, as in the crushing at the south boundary; but I rather think that the diametrically opposite direction of the dip suggests an independent, prior, period of disturbance; one probably connected with a depression of the area of the Shillong plateau, which, it would seem, was defined as a mountain area, with approximately its present base, previous to the out-pouring of the trap.

The opinion I have just expressed is based upon the nature of the junction of the trap with the metamorphic rocks. I first examined this junction in the glens of Liam and Soktia. The system of secondary valleys to which these belong is manifestly determined by the junction of the trap. In those two glens the line of contact is so remarkably

steady in its east-west course that I was led to suppose a fault. Along the stream under Soktia none but crystalline rocks and their debris occur on the north bank; occasionally in the river bed, and generally on the south bank, the earthy amygdaloid is well seen, apparently with a high dip towards the junction. In the bed of the stream there is much debris of a dark rough basalt, with much clear olivine, derived no doubt from some bed or dyke in the trap farther up the glen. Immediately above the confluence of the Soktia stream the main river debouches from its narrow rock-bound gorge through the metamorphic rocks into the comparatively open valley across the belt of trap. The cane suspension bridge stretches from pier to pier of porphyritic gneiss and gneissose quartzite, the very last mass on the north side of the boundary. The actual contact is not visible; nor can its underlie be fixed; but it must be very steep. The trap is not exposed for a score of yards below the metamorphics; there are both earthy and stony varieties, but the structure cannot be clearly made out. I did not observe any signs of intrusion in the rocks on either side of the junction here. At the very head of the Liam glen, at the confluence of the head-waters, the contact is exposed: the trap here is all of the compact kind; and strong dykes of it, with transverse prismatic structure, traverse the main mass and seem even to penetrate the granitic rocks for a short way. There is no clean-cut plane of contact; it is irregular and entangled, as it might be by the trap having flowed against a rugged surface of the crystallines.

It was in the valley west of Mámluh that I made some conclusive observations upon the relation of the Silhet trap to the crystalline rocks. In the saddle of the ridge to the south of the village, the surface of the trap is at an elevation of about 2,800 feet over its lowest observable level; so this may be taken as a minimum thickness for the formation. The ridge of the Tàrna spur is about 210 feet lower than the top of the trap, this upper portion being entirely composed of the

most earthy and ash-like forms of the eruptive rock. The little ridge of the Tarna spur is formed of metamorphics; and I found an excellent section of the earthy trap resting on the quartzites. On descending northwards from here to the river under Nongriath and ascending again by the spur west of Mámluh none but metamorphic rocks are seen, with some strong bands of dense dioritic rocks associated with them. On descending the Tàrna spur westwards by the path to Ramdai one crosses a small patch of the earthy trap at about half-way down; but with this exception the metamorphic rocks last the whole way to the village. The stratified trap appears again just to the west of Ramdai and continues for the whole way over the spur to Tenrong; it is evident, however, that the cliffs to the north must be supported on the metamorphics, for the debris of these rocks is abundant all along the path. Again we find the outer ridge of the Tenrong spur to be of metamorphics, and they last the whole way down to the Bogapani. Close above the river there are numerous symptoms of the Silhet trap, and in the rocks exposed in the bed and banks of the torrent there is a grand display of the trap cutting through the quartzose schists, in a perfect net-work of veins. I was so pressed for time that I could not attempt the difficult work of following down the section to the junction of the main trap, which I imagine not to be far off; but I have no doubt that these veins belong to the Silhet trap; they are quite unlike anything I have seen in the older trap. Unfortunately the rainy season set in before I could follow up my investigations of these interesting sections.

The section described in the last paragraph, from below Mámluh due west to the Bogàpàni, is exactly on the run of the boundary in the glens to the east; but it shows conclusively that the junction is in no manner a faulted one, and that the trap was piled up against a precipitous face of the metamorphic series. The section in the Bogàpàni below Tenrong is a more complete case of what was observed at the

head of the Liam glen; showing that the trap, at least locally and at the lower levels, could be highly intrusive, even penetrating for some short distance into the hard metamorphic rock. This is the more remarkable, as it is only in this position, near the contact, that phenomena of intrusion have been observed with this trap. At still lower levels, in the Theria river, earthy highly amygdaloidal and well-bedded trap predominates, and I did not notice there a single case of later intrusion. But my observations are too few and too scattered to suggest a presentable explanation of these peculiarities.

It will have been noticed from the foregone remarks that there is much variety in the rocks of the Silhet trap formation. Some of the gray and dull claret-coloured amygdaloids with green-earth and olivine are very like common forms of the great Deccan trap. It seems probable too that a detailed examination in the field will disclose some order in their arrangement. The two or three hundred feet of soft ashy beds noticed just south of Mámluh seem to be to some extent characteristic of the upper part of the series; and from the absence of these beds in other places, as along the southern boundary, the formation seems to have undergone much denudation prior to the commencement of the cretaceous period.

A trap formation of such great thickness must have had a correspondingly wide horizontal range. We seem to have here its original northern limit. There is no surmising how far it may stretch to the south beneath the present delta and the bay of Bengal, being still further buried beneath the remains of the cretaceous and tertiary deposits which seem to have also extended in a southerly direction. To the west the trap has not been noticed beyond the region of the Umblai, but this is manifestly due to concealment beneath the sedimentary series. To the east it seems to become concealed in a similar manner, as if still overlapped by the cretaceous beds. There is certainly no trace of it under these rocks on the Kopili or the Námbá, no more

than at Singmári. Its range would seem to be connected with the area of disturbance, which was also one of subsidence.

7. General Stratigraphical Features.

The peculiar position of the Shillong plateau, as an elevated area of horizontal ancient sedimentary rocks, has been mentioned—that it lies in an acute angle between two regions of special disturbance and of 'true mountains.' On the north, on the side of the Assam valley, the basal gneissic rocks of the plateau present a continuous front to the Himalayas. All apparent connection of the distinctive sedimentary rocks of the table-land is with the region to the east and south-east, where these same groups of rocks, in immediate proximity to, and directly continuous with, the strata of the plateau, are intensely disturbed and form rugged mountain-ridges, overtopping the level of the plateau. The discussion of these phenomena of disturbance would belong mainly to the geology of this mountain region; but the important features at the limit of disturbance must equally be noticed in connection with the table-land, and there are collateral facts to be observed in the table-land area having essential bearing upon the argument. Most of these have been mentioned already, but it will be well to bring them together.

The leading stratigraphical feature of original standing in the great series of unaltered sedimentary rocks is, that there was here the limit of a great basin of deposition. There is throughout the whole section from north to south a steady thickening of the formations, with the substitution of marine deposits for those that would seem to have been alluvial and diluvial. This has been described in detail in noticing the cretaceous strata of Cherra. The same feature was observed in all the sections to the west: about Harigàon the cretaceous sandstone is banked against a steep face of crystalline rocks. From the examination of the Silhet trap it was shown that the existence of a mountainous mass of metamorphic rocks, having approximately the same southern limit as the present plateau, is of very ancient standing. However different the height and

form of this mass may have been at the period of the Silhet trap, it had assumed approximately its present form along a very wide margin before the cretaceous period, as is shown by the distribution of the outliers of the cretaceous strata; so that the materials for these deposits, which were probably largely derived from that quarter, must have come from a considerable distance further north. The culminating line of the crystalline area then may have been over the present area of middle and lower Assam, or may even have joined on to the Himalayas. The changes of level that took place during the disturbance that produced such ranges as the Burrail, at a time well advanced in the tertiary period, may well have led to the extensive erosion of the Assam valley. There is some evidence for this in the distribution of the drainage: in the eastern portion of the plateau, the rivers flow northwards right across it from the Burrail, or rather from the edge of the area of disturbance.

The one main stratigraphical feature of origin subsequent to the formation of the unaltered sedimentary series is the continuous semi-anticlinal flexure on the east and south boundary, along which all the strata bend down into the area of disturbance. This structural phenomenon indicates, at least *primâ facie*, that the initial movement within the area of disturbance was one of subsidence. The age of this break-up has not yet been fixed, for want of fossil evidence; but it would seem to have been well advanced in the tertiary period, for there is a very great thickness of supra-nummulitic deposits, which have been accumulated in unbroken parallelism upon the cretaceous beds of the plateau, and which maintain that parallelism where all are highly inclined. Some local appearances of unconformability have been described, and many more such may be observed, without shaking the main fact that no general contorting force acted upon this great sedimentary series until after the deposition of its latest member.

It will be at once perceived what a striking example the conditions of this area afford of the theory of M. M. Herschell and Babbage

regarding crust-movements. The Silhet trap too appears just in the proper position, between the area of erosion and of deposition, on the axis of oscillation or of weakness; only, to be completely illustrative, it should be intrusive into the younger deposits. It may, however, retain its position in this relation, if we take a wider view of the case: it is scarcely to be supposed that these lines of disturbance were first struck out at the recent period assignable to the formation of the Burrail range, so that the trap-flows may belong to some much older period of activity in the same system of depression and contortion.

It is equally plain that the facts described afford a strong *primâ facie* example against any rigid interpretation of M. de Beaumont's theory upon the rectilinear character of cotemporaneous features of disturbance: here we find one and the same great axis of flexure, some hundreds of miles in length, bending round at half a right angle. But this objection in its turn may be qualified by the remark that the bend occurs where the magnitude of the mountain range begins to decrease.

The fact just noticed indicates another coincidence in illustration of the theory that connects disturbances of strata and mountain formation with the accumulation of deposits. There is no doubt but that the extension of the Burrail ridge westwards has been a good deal curtailed by denudation; but it seems more than probable that this extinction of the range is causally connected with the decrease of disturbance that takes place in the same direction; and that this again has a similar relation to a decreased thickness of deposits. This decrease westwards is not very clearly seen in the cretaceous strata. The coal-bearing sandstone is the only cretaceous rock in the western sections, and it is very much thicker than the same band in the Cherra sections; but then it is not now known whether this rock in that region may not represent a great part of the whole series at Cherra; nor can it be known that the marine beds of Cherra do not occur in the southern underground extension of the formation in the Gàro region. Again, the characteristic rocks of

the nummulitic formation at Cherra are certainly reduced to a mere shadow near the Bràmàhpùtra, but until the true limits of the formation are known, it cannot be asserted that the whole formation decreases westwards. It is in the supra-nummulitic deposits that this change is most remarkable; but we must go further east than Cherra to notice it: there is an enormous thickness of upper sandstones in North Cachar that can be but feebly represented at or west of Cherra; and it is precisely with the loss of these rocks that the most conspicuous results of disturbance disappear.

In the western region, where the magnitude and intensity of the disturbing action is so much reduced, we obtain observations, probably better than are to be had elsewhere, upon the *form* of the disturbance. The facts have a two-fold interest: one, in so far as they corroborate what has been said upon the agreement of the stratigraphical features of this region with a well known theory of a natural sequence for these complicated phenomena; and secondly, in so far as they may supply a link in that theory by suggesting a partial law for the ***modus operandi*** of the process postulated by it. In the section of the Theria river there is but one continuous dip to the south; it is lowest in the bottom strata, increasing steadily to the vertical in the outermost and youngest (supra-nummulitic). In the Bogàpàni, only seven miles to the west, this feature is modified: the average dip is higher, but at the river's edge on both banks, the bottom nummulitic limestone and its covering sandstone, from a southerly dip of 70°, suddenly become almost horizontal; the unbroken continuity of the beds in the sharp bend being well seen. They continue thus for about half a mile, with a southerly slope of 3° to 5°; the sandstone becoming covered by the second band of limestone, which forms low cliffs on the left bank. There is then again a sudden turn down to the south; and the section ends, all the younger strata being denuded. It is on the Suméṡari, where the section at the base of the plateau is fourteen miles wide, that these flexures are well seen. They are repre-

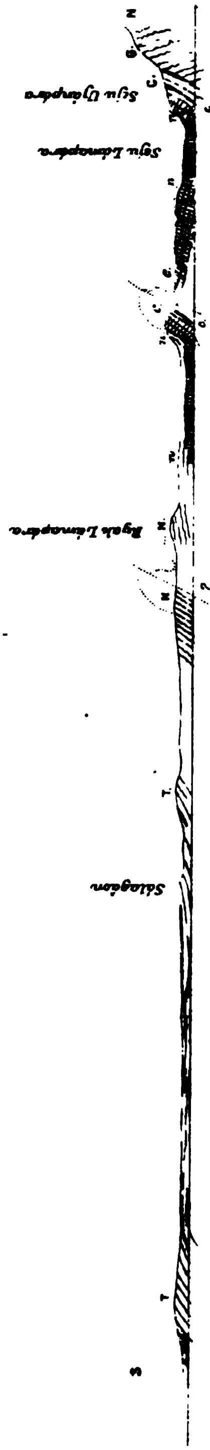


Fig. 3. Section on the Sumésari river.
T, Supra-Nummulitic. N, Nummulitic limestone. C, cretaceous; c, coal. G, gneiss.

sented in the figure (3): at the outer edge of the hills the highest beds of the series have a dip of 40° to the south; a short way up the river, they have become horizontal or flatly undulating. Where these beds are last seen, above Sàlàgàon, they have a steady rise to the north. The next rocks have more the character of the nummulitic sandstone; they have a high southerly dip. Ryak Làmàpàrà, a little higher up, is on a ridge of such a sandstone, probably a repetition of the same beds, having a moderate dip; and in the valley of Ryak Ujanpàrà the nummulitic limestone is at the surface quite horizontal; it runs so up to the base of a steep ridge, and here turns up abruptly along the surface of the cretaceous sandstone;—a bend exactly like that on the Bogàpàni. The cretaceous coal occurs along the north flank of this ridge. After a short blank section the same cretaceous sandstone appears along the river's edge, having a very low northerly inclination, which brings down the limestone again, resting on the sandstone. A quarter of a mile further north, close to Seju, both rocks turn up in a similarly abrupt manner against the base of the ridge of gneiss. The ridge north of Ryak is the best example of the first point indicated at the commencement of this paragraph,—of the features which suggest a compressing force from the south;

the structure of this ridge has all the appearance of a normal or a folded flexure, of which the axis-plane underlies to the south, towards the area of depression, and thus points to the direction of the lateral pressure, from that area.

It appears at once from the several sections described, that features such as that just indicated are exceptional; that most of the normal flexures have their axis-planes sloping northwards. It will be recollected that Mr. Rogers (whose terminology for the forms of plications I adopt) regarded flexures as true undulations proceeding from the focus of disturbance, arrested and fixed by lateral pressure. By such a mode of formation, the axis-plane must incline towards the origin of the wave; but Mr. Rogers' hypothesis of causation was scarcely maintainable. Still it might be considered that in any natural process for the production of unsymmetrical flexures, the axis-plane must, from first to last, have that constant relation to the source of the pressure,—that the shorter and steeper side of the anticlinal curve should be on the side further from the compressing force. It is most unlikely that any such absolute rule should exist, the conditions of action and of resistance being so variable; and it is only by the examination of the most simple cases obtainable that we can arrive at rules for general guidance, by which we may be able to detect exceptional cases where the form of a flexure was determined initially by peculiarity of position. In discussing elsewhere (Mem. Geol. Surv., India, Vol. III, Pt. 2) a phase of this question as to the forms and causes of contortion in which the pressure is that exercised by a mountain-mass upon the strata at its base, it was seen that the axis-planes of the flexures do conform to the rule of underlying towards the source of pressure, although it did not appear (page 124) that when the flexure became faulted, the upthrow was always on the same side as required by Mr. Rogers' hypothesis. Allusion was made (page 170) to what might be the case where the contorting force was that derived from the sinking of the strata themselves. It would seem

that the area now under notice affords an excellent example of such conditions: we have seen that all the leading circumstances suggest this hypothesis, and I have adduced the folded or faulted flexure north of Ryak to corroborate this view; it seems, indeed, self-evident that the force which produced this feature was directed from the south, the axis-plane being also inclined to that point. It has been observed, however, that this is by no means generally the form of the flexures in these strata; the case is decidedly the reverse; the normal flexures, whether uniclinal, or anticlinal with one slope very flat, have their axis-planes underlying northwards. So much is this the rule that, if from other considerations it can be independently established that the contortions in this region are the result of a depression to the south and the consequent compression of the strata, it would be inferable that one result of such a process, at some stage or other, is the production of normal flexures having their steeper sides towards the basin of depression, or, having their axis-planes underlying *from* the centre of subsidence. It would be valuable to know what light the abstract consideration of the case could throw upon the law thus indicated.

Once the form of the flexures is struck out by any initial stage of movement, all subsequent action must be guided thereby. In this way, it has occurred to me that the feature north of Ryak may not be a *bonâ fide* normal flexure of the kind described, one that from the beginning had its present southerly underlie. It may well be that a further, or a slightly different, lateral pressure might produce such a feature out of one of the ordinary normal flexures of the district with a northerly underlie, such as that seen at the south end of the section. The composition of this ridge at Ryak encourages such an interpretation: the thick band of shales accompanying the coal that occurs in about the middle of the cretaceous group here, appears just along the north flank of the ridge; and it is tremendously crushed. The slipping or faulting, which the supposition I make requires, would seem to have taken place along these

soft beds. Similarly in the other example shown in the section to the south of Ryak: if the sandstone at Ryak Lamapara be a repetition of that to the south, as seems to me likely, the slipping would have found the same encouragement in the soft clays that occur between the sandstone and the nummulitic limestone.

8. The Gneiss Series.

On the Shillong plateau, which is orographically a portion of the great Central Asian rock-area, the geologist has to encounter the feature which is such a difficulty and disappointment to him all over the rock-area of the peninsula of Hindustan—a total and incalculable stratigraphical hiatus between fresh-looking strata having almost a superficial aspect (however ancient some of them may be), and great sedimentary formations, both metamorphic and unaltered. Rocks of both these latter types are represented in the Shillong plateau: there is an ancient gneiss, and also a series (largely developed in the Khasia district), which I will call the Shillong series. I can only speak cursorily of all these rocks; my attention having been directed chiefly to the more recent formations.

As separately examined, there is a very wide difference between the gneiss and the Shillong series. The latter, over large areas, is only submetamorphic, consisting of schistose clay-slates and granular quartzites; but I cannot say with what precision the boundary between the two series can be laid down, having crossed it only in the low jungle-covered hills on the Assam side, north of Shillong. On the plateau the boundary would pass in a south-south-west direction between Maophlong and Nungklao, a region I have not visited; but from descriptions of the rocks about Nungklao, I have little doubt they belong to the older series. The bare massive dome-like features of the Kallong rock may be almost said to be characteristic of the granite or granitoid gneiss of the older metamorphics. Such masses are very common throughout lower Assam. The true granite so largely associated with the Shillong series never makes any approach to this structure.

I imagine that the boundary can be clearly made out, for, as far as I have seen, the greatest metamorphism of the Shillong series takes place towards the south-east, away from the area of the older metamorphics.

All the metamorphic rocks I saw in the Gàro district—at Seju, Tùrà, Harigaon, Singmàri—I considered to belong to the gneiss. So also were those in the far north-east, at the falls of the Kopili, and on the Nàmbà near Golaghat.

9. The Shillong Series.

This series and the igneous rocks connected with it form the basis of the table-land throughout the whole section of the Khasia district—from Cherra on the south to the Dinghei and Màsura ridge beyond the Umiàm north of Shillong. It is of course a venture to speak of it as one series upon so slight an acquaintance, for it comprises a great thickness of strata showing considerable variety of composition. It would be only still more venturesome to attempt a separation upon the same information. In any case, there are the important characters in common of general parallelism and of equal and local metamorphism.

The series consists of a considerable thickness of quartzites, locally largely conglomeritic, and of an unascertained thickness of earthy rocks in the state of slate and of schist. The distribution of these rocks seems to have but little connection with the actual configuration of the table-land. The same may be said of the contortions displayed in the strata; it will, indeed, be difficult to bring these structural features into any general order, the observed differences of strike are so great. But the area over which they have been observed is too small to afford data for discussion. Intimately connected with the deposits of the Shillong series, there are large developments of hypogene rocks, both trappean and granitic.

The two types of deposit forming the Shillong series are not indiscriminately associated; they occupy distinct positions, and must have been deposited consecutively. As far as I have been able to form an

opinion, the argillaceous rocks underlie the quartzites. The only area in which I have seen the former well exposed is in the run of low ground along the west flank of the Maophlong ridge; indeed, I cannot be certain that the rocks here exposed occur anywhere in the region I have examined to the east of this line; subordinate runs of schist do show locally in the valleys to the east, but they may be associated immediately with the quartzites. It is certain, however, that the same quartzites occur again to the west, within the main area of the schists. Along the west flank of the Maophlong ridge, there are many continuous sections seen across the strike of the rocks at the junction of the quartzites and schists. All the strata are nearly vertical, so that a slight tilt on either side produces opposite underlies and opposite superpositions. For many miles the junction runs in a steady north-north-east course corresponding to the strike of the beds. The quartzites of the ridge affect a very general easterly underlie; and the same prevails at the junction and in the slates or schists near it. This is the most positive fact upon which I accept the quartzites as the younger member of the series. Elsewhere also, where more earthy rocks are exposed, it is in the valleys, and apparently underlying the quartzites.

In the middle region, about Maobelarka and Laisoplia, a thick band of conglomerate is very largely exposed associated with the quartzites. It presents like characters everywhere, though apparently of variable thickness; it is almost exclusively made up of quartz pebbles, of four inches diameter and under, but pebbles of coloured quartzites also occur. It may be presumed to belong to one and the same band; and the position of this band can be clearly fixed. For several miles along the Maophlong junction, this conglomerate is the rock in contact, forming the base of the quartzite group. It is about 100 feet thick; and the lower portion is decidedly coarser than the upper, and has a more earthy matrix. The variability and local character of the conglomerate is also well seen on this line: although steady and conspicuous for some miles to

the south-west of Maophlong, it is not continuous; there is no sign of it about the junction in the unbroken section due west of Maophlong, nor for some miles to the north. It was observed, however, in an analogous position, between the quartzites and the schists, in the sections of the valley of the Umiàm, and on the north side of the Másura ridge, which is the northern limit of the plateau. The rocks are so completely folded that this band is found at all elevations, in the bed of the Bogàpàni as on the ridge of Laisoplia.

The area of the schists has been very little explored. They present a considerable variety of composition, texture and colour; some are still soft and shaly; others show partial cleavage, and in some foliation and mineralization are well developed. The quartzose element is very subordinate. The study of the schists is greatly obscured by the extent to which they are traversed by, and associated with eruptive rock; over large areas, the two seem inextricably blended.

The quartzites are not perhaps of greater thickness than the schists, but they come much oftener under notice, being conspicuously weathered out on all the ridges. As far as is in their nature, they exhibit as much variety as the others. Some of these characters must be due to original differences; there are compact, sharply bedded varieties and also coarse forms, in which false bedding is as clearly seen as in the original sandstone. So much do they locally and superficially resemble unaltered rock that they have been over large areas mistaken for, and identified with, the cretaceous rocks of Cherra. Unless where the disintegration is far advanced, a lens always enables one to detect signs of metamorphism. But metamorphism is irregularly, and apparently capriciously, distributed; it seems to have little or no relation to the proximity of the great granitic masses which, as will be explained, appear to have been protruded through them. It would seem rather to be locally connected with the degree of disturbance; thus on the Maophlong ridge, where the strata are nearly vertical, with

a north-north-east strike, foliation is strongly marked; while on the Shillong ridge, with a general east-west strike, the dip is often flat, and the foliation is scarcely traceable. Elsewhere, however, where the contortion is extreme, the granular texture is preserved.

Although such capriciousness of lithological characters is common over a large portion of the area, there is one very well marked tendency observable when the whole extent of these rocks is considered. There is on the whole a complete change of condition from north to south. In the Shillong region, and even to near Surarím, crystalline metamorphism is only incipient or partial; in the south, it is complete and general. I have scarcely a doubt of the identity of the series throughout: I have followed the rocks continuously down the valley under Surarim into the valley of Nongpriong below Cherra, and so to the southern boundary with the Silhet trap. In this region, gneiss shows freely, associated with the quartzite, and, we may suppose, in great part formed out of it. There are other concomitant features hereabouts: dykes, large and small, of granite are frequent, cutting the strata in various directions; such phenomena, as far as my observations extend, being altogether wanting in connection with the great granite masses to the north. There is, at the same time, a decided prevalence of an east-west strike in the complicated contortions affecting the strata here.

Should the feature I have described in the last paragraph prove to be general along the southern fringe of the table-land, as I opine it will, it would involve an important modification of a statement made in the second paragraph of this Section, regarding the independence of the structural features of the Shillong series with reference to the configuration of the table-land. That observation must remain true of the main area of these rocks; but it would be most interesting to find that the area immediately south of the plateau, which has been shown to have been more recently an area of very extensive trappean eruption, and subsequently again an area of special disturbance, had been in very

remote times a region of granitic intrusion and a centre of metamorphosing influence.

If I were to conjecture an identification of the Shillong series with rocks known in other parts of India, I would point out the decided similarity of composition, of order of succession, and of condition to the quartzites and schists of Behar, as seen in the hills of Rajgir and Gya.

10.—The Khasia Greenstone.

Within the area of the Shillong series, at least in its middle region, eruptive rock occupies nearly as much place as either of the sedimentary groups. The high road between Surarim and Maophlong passes continuously over greenstone for about half the way, with the exception of about fifty yards on the Maobelarka ridge, where a gap is cut through the capping of cretaceous conglomerate: from near the top of the descent into the valley of the Kalapani, over the Maobelarka ridge, along the valley of the lesser Kalapani, across a branch of the Màokàleng ridge and down to the very bottom of the deep glen of the Bogapani, the greenstone is perfectly continuous for a distance fully five miles. This line is no doubt oblique to the run of the rocks; but in places the outcrop of the greenstone is certainly more than a mile wide; and locally it reaches to the full mean height of the plateau. It is undoubtedly an igneous rock, a dense, basic trap in which the felspathic element is very subordinate. It affects various structures, angular and spheroidal, rarely sub-columnar.

It is the gisement and the allure* of this rock that are obscure. I could nowhere discover a sign of any portion of it being cotemporaneous, as interstratified, with the sedimentaries; nor does itself ever betray a bedded arrangement. Lithologically, moreover, it has none of the characters of subaërial volcanic rocks. It is then intrusive; yet,

* It is with some compunction I make use of these foreign words; but I have often sought in vain for English equivalents. By *gisement* I mean here the circumstances of arrangement proper to the rock—whether bedded or amorphous and intrusive. By *allure* I mean the external relations (behaviour), to associated rocks.

notwithstanding its great massiveness, and hence the presumable energy of the irruptive action, it is striking how little collateral evidence there is of such action. In the low ground to the west of Maophlong there are numerous cases of strong dykes cutting across the strike of the schists, and proving fully the locally intrusive character of the trap. In the quartzites such instances are very rare: I have walked for miles along the contact of broad masses of trap filling the ground between strong ridges of quartzite without finding ever so small a case of penetration by the trap; and where these valleys of trap run into each other it seems to be mostly at the folding and elevation of the quartzose strata. I only know of one instance of a trap dyke cutting boldly across the quartzite; this dyke determines a saddle in the ridge at half a mile to south-south-west of Maophlong; the strike of the quartzites being steady against the sides of the trap on both sides. The base of this dyke is seen under the road at the north end of the cutting for the approach to the Bogāpani bridge. Over the great surface exposed, I have not seen any case of intrusion into the trap by trap.

Although then this rock would seem to be altogether introduced into the Shillong series since the completion of that series, and by one continuous process, it affects a definite position in the series: not only do we find it associated with the schists, in the ground to the west ot Maophlong, in a far more abundant and more intimate manner than with the quartzites, but even in the region to the south-east of Maophlong it seemed to me as if the great runs of trap along the strike actually occupied the position of the schists,—where these would now be but for the introduction of the trap. All about Maobelarka and Laisoplia the conglomerate band is in contact with the trap and presumably rests upon it or rather in it. It seems to me necessary to suppose that the trap has in many places and to a great extent absorbed and assimilated the schists.

The features I have described seem to me most compatible with the supposition that the introduction or formation of this trap was cotemporaneous with the principal contortion of the series. When examining the similar stratified series in Behar, in 1863, I was led to make an analogous conjecture regarding the trappoid and quasi-intrusive rocks there. The evidence there for the, in great part, local origin of the trap was supported by the fact that in the older metamorphic rocks close by there were little or no signs of similar intrusive rock. This point of evidence is probably to be found in the Khasia hills. In studying the metamorphic rocks of Western Bengal my colleague Mr. M. H. Ormsby has made an analogous distinction between igneous rocks more or less intimately associated with the contortions of the strata, and later igneous rocks cutting all with little regard to pre-existing structure; the former he indicated by the name of hypo-cotemporaneous, or hypo-synchronous, a term that conveniently expresses the opinion and the relation indicated.

11.—The Granite.

It still remains to notice the granite, of which two principal expanses occur. Within our area these are only found in contact with the Shillong series; but their limits to the east and west have not been traced. The most northern of the two has been described as the granite of Molím; it extends eastwards beyond the area examined; the road between Maophlong and Shillong runs for some miles close to its western and northern boundary; between Lailángkot, on the south, and Shillong it is five miles broad. The southern area seems much larger: its boundary approaches from the north-north-west to near Surarim; here it bends southwards, passing about half way between the scarp and the bottom of the valley under Surarim; at the head of the Nongpriong valley there is a narrow slice of the granite exposed, the boundary passing westwards under the cretaceous rocks. I did not fix the exact position of the south boundary in the valley of the Bogàpani; the granite is continuous there from

below Kokon on the north, to as far as Maplai; where I next observed the rocks, under Tenrong, the Shillong series is in place. In a direct line along the Bogàpani valley this granite must be ten miles wide.

The relation of these great masses of granite to the Shillong series puzzled me much. The commonly received special evidences of intrusion are very obscurely developed; and still less evidence is there for the supposition that the deposits of the Shillong series were accumulated around, or upon, the granite. Although in this latter case, one need not expect to find identifiable debris of the granite in the sedimentaries, it is scarcely conceivable that such an original symmetrical arrangement of the strata around the crystalline mass could by any amount of subsequent contorting action be so utterly obliterated as we find it to be. This same absence of all symmetry in the arrangement of the strata with reference to the foreign mass is also not in accordance with at least one aspect of the supposition of subsequent intrusion—the slow introduction of so great a mass would, one might think, impress some regular structural feature upon the invaded stratified rocks contiguous to it. Again, the more one renounced this aspect of intrusive action the more would *a priori* considerations seem to require the presence of direct and special evidences of a more energetic intrusion, in the form of dykes and offshoots traversing the strata regardless of position; but of such I have not been able to find any.

The granite is, on the whole, uniform in texture and composition. As well as I can determine by simple inspection it contains—pale pink orthoclase often in large crystals; a much smaller proportion of very pale greenish, striated felspar which I take to be oligoclase; an abundance of hyaline quartz well disseminated, and a small proportion of dark green or brown mica. The rock constantly affects a spheroidal structure. The forms of these granitic areas are broad; if elongated the width bears a high proportion to the length; the ends are blunt. The boundary is almost everywhere well defined, and there is ample opportunity for

observation; yet, although my examination was pretty close, I did not notice a single case of protrusion from the granite into the sedimentary rocks, nor any dykes, great or small, in the neighbourhood that might be referred to such an origin. On the part of the Shillong series there is little or no betrayal of special metamorphism along the contact—the strata are not noticeably more mineralized here than at many places far removed from the granite. Stratigraphically this indifference is even more marked: the quartzites, the highest member of the series, are the rocks most frequently found in contact, but they occur in every position—striking against the boundary at any angle of obliquity, or dipping at it or from it at any angle of inclination. All these conditions may be observed along the west boundary of the Molím granite between Lailángkot and the south-west base of Shillong hill. The only good case of irregularity of outline with apparent mingling of the rocks on this line is at the point of the ridge west-north-west from Lailángkot. The rib of quartzite upon which the village is built projects obliquely into the granite; and this latter projects into the angle on the south side of the ridge; but even here there is nothing like a dyke. The mutual reactions of the rocks are, however, very observable.

The same remarks apply in a great measure to the granite of the western area. It lies mostly in the deep gorges of the southern region of the plateau, where everything is unfavorable to observation. There is the same indifference of the strike of the strata to the position of the granite; the same absence of general contact-metamorphism and of special intrusive action. The line of contact can sometimes be traced by the eye up the steep sides of the deep valleys; it is always nearly vertical, with a small underlie towards the quartzites. In the bed of the Kálápáni under Surarim on the north-west the contact is poorly exposed: it is somewhat irregular, and there are decided effects of special metamorphism. On the whole, there can, I think, be little doubt that these great granite masses are truly intruded.

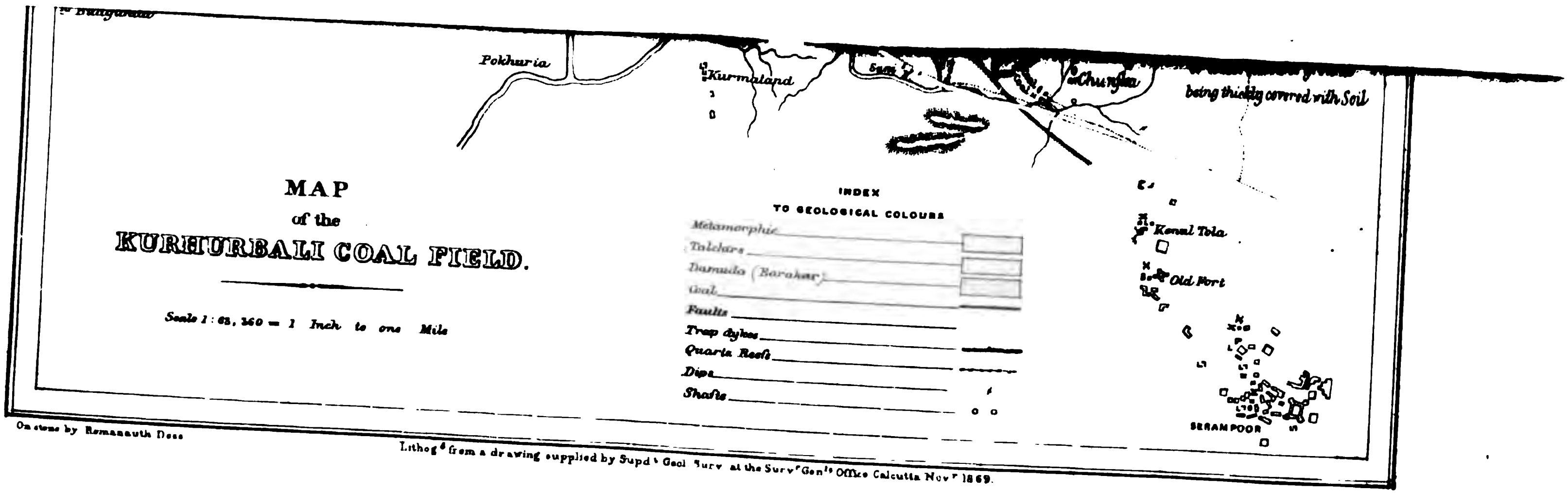
The absence of local intrusive phenomena in connection with the great granite masses is the more surprising when we come to observe in the southern region the frequency of such special intrusions of a similar granite. These are not either always in the form of dykes; there are miniature protrusions on the pattern of the large masses. Such features are more common than would appear at first. It is only possible to observe along the paths; and these are almost always made on spurs or by ladders down cliffs, formed of the harder quartzose strata; owing to the more ready disintegration of the granite, it is generally impossible to find in place the rock of which huge blocks are found abundantly in the torrent bed, and which must be derived from some outcrop within a short distance up the enclosed gorge. The best instances of these intrusions that came under my observation are on the east side of the valley of the Theria river, near the boundary of the Silhet trap: at the village of Turingai there is a good sized boss of coarse granite; and in a little valley a quarter of a mile to south of the village there is a two-foot dyke of the same rock cutting across a mass of quartzite.

The relative age of the trap and the granite is a point of some interest; and my observations go to prove that the granite is the younger of the two. I only in one spot found the Khasia greenstone in close contiguity with the granitic masses. This occurs at the point south of Maòreng, where the boundary of the Molím granite takes its sharpest turn; and again in the stream half a mile to south-east of this bend. The actual contact is not exposed; but both rocks are in place and apparently quite normal within five yards of each other. Thus the trap forms no exception to the neutral relation of this granite to the rocks along its boundary. I have never seen any trace of the greenstone penetrating the granite; but in the bed of the torrent below Surarim on the east there are several clear sections of small dykes of granite ramifying through the trappean rock. The general direction of these dykes is with the strike of the quartzites, which is here parallel to the boundary

of the main southern granitic mass, high up on the western side of the valley; there being no apparent connection of the dykes with this mass. The mutual influence of these dykes and the containing rocks is very small indeed; the granite is less granular and less uniform than elsewhere; but there is still plenty of free silica, and without any sign of a hornblendic mineral; there is even less mica than in the main granite.

I have again in this section to point out the similarity with the Behar rocks: they too are invaded by a granite, and apparently of later date than the origin of their trappean rocks.

N. B.—In the text I have endeavoured to give the local proper names in the Jonesian form of transliteration, on the map the names are copied from the Topographical Survey sheets.



On stone by Romanauth Dass

Lithog.d from a drawing supplied by Supd.t Geol. Surv. at the Surv.r Gen.l's Office Calcutta Nov.r 1869.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

The KURHURBÁRÍ COAL FIELD, *by* THEO. W. H. HUGHES, F. G. S., *Associate Royal School of Mines, Geological Survey of India.*

CONTENTS.

The Kurhurbárí field* in the district of Hazaribagh, although in size ranking amongst the smallest of the coal-bearing areas of our Indian empire, has, for the last 15 to 16 years, attracted the attention of Government and of private individuals, owing to the generally admitted superiority of its coals to those from any of the fields of the Damúda valley, and of its position as a source from whence to supply the wants of the East Indian Railway and the larger towns west of Dinapore. Those, however, who have so strongly upheld the advantages possessed by the Kurhurbárí field, seem to me to have failed

* On the map, *l* replaces the *r* in *bárí*, in order to retain the popular pronunciation of the name of the field.

when desirous of making a true valuation of its resources, in giving sufficient weight to the drawbacks of its limited area, the character of its seams, and its geological structure.*

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* The following report on the Kurhurbárí coal field has been drawn up by Mr. Hughes, but the information contained has resulted from the labours of several officers of the Geological Survey. I cursorily visited the field so long since as 1852. No maps whatever then existed of that country. Attached to Dr. McClelland's report, there was a map of a part of the coal field prepared by Mr. Haddon, an excellent surveyor attached to Dr. McClelland's party in 1848-49. Indeed, in many respects this map is superior to any since produced. As soon as it was possible to procure copies of the Survey map of that portion of Hazaribagh, I deputed Mr. W. L. Willson to examine this coal field in detail. At that time (1859), the East Indian Railway Company were carrying on vigorously the working of the field, and under the very intelligent and zealous guidance of Mr. Cockburn, their Resident Engineer, much was done to elucidate the structure and area of the coal-bearing rocks. Borings were very systematically carried on while the raising of the coal continued. Unfortunately, however, the topographical map furnished to us was so entirely deficient and erroneous that it was impossible to make use of it, and I was unwillingly compelled to remove Mr. Willson, as it was only waste of time to attempt recording our observations on such a document. After the ground had been resurveyed, Mr. Willson returned and completed the examination of the field.

Meanwhile, however, the workings of the East Indian Railway had entirely ceased, and no further information was to be obtained by actual examination of the coal workings. In fact, nothing whatever was at that time being done in the field. The map having again been improved, and working having been in part resumed, Mr. Hughes was requested to go over the field again, and add to the geological map any information which could be gleaned from recent workings, and to correct anything which might appear needful, or which might be better seen now than in previous years. This was done during last season, and his report, in which the information obtained in former years and by others is embodied as far as appeared necessary, is now published.

The only workings, at present in actual operation, are those of the Bengal Coal Company, who have been very vigorously raising coal for some time past, in anticipation of the demand for the railway on the opening of the "Chord Line," and have further been wisely proving the extension of the beds of coal within their property, and with much success. Nothing has yet been done towards re-opening the works which had been carried on by the East Indian Railway, so that there has, unfortunately, been very little opportunity of obtaining information such as can only be obtained from actual workings as to the nature and continuity of the coal-beds. The report is, therefore, unavoidably less full and satisfactory on these points than it was hoped we should have been able to render it.

T. OLDHAM.

II.—Previous Observers.

Dr. McClelland.

The first who prominently brought to notice the Kurhurbárí field was Dr. McClelland, who examined it geologically during the latter part of the year 1848, and published a report enunciating his views in 1850. This was a valuable contribution, and looking to the difficulties of the ground, the entire absence of maps to work with, and the fact that nowhere had the coal been opened out, it is not surprising that some errors crept into Dr. McClelland's statements. He certainly misinterpreted the stratigraphical evidence in the north of the field, and formed an excessive estimate of the total thickness of strata and coal. By 'actual measurement', Dr. McClelland gave 12 beds of coal, amounting to 80 feet 6 inches:—

1	At Koomarsote	1	bed	4′	6″
2	„ Kooldeeha	1	„	4′	0″
3	„ Domahanee Ghat	2	„	9′	0″
4	„ Oopurdaha Ghat	3	„	15′	0″
5	„ Suttee Ghat	3	„	33′	0″
6	„ Jacoota	1	„	10′	0″
7	„ Ramnuddee	1	„	5′	0″
		12	„	80′	6″

By estimate, (Par. 136) he makes the number of seams twenty, and the total thickness 92 feet.

The quality of the coals is stated, in almost every section, to be "superior". This term, superior, however, seems to have been indiscriminately applied to shaly coals, slaty coals, and bituminous coals. One of the Koomarsote nuddi coals (Par. 138) is spoken of as being at once of a *slaty* character, and *superior* quality.

The capabilities of the field are alluded to in the following terms (Par. 7) :—

"The new coal field, although of small extent, is rich in valuable beds of coal, capable of supplying all demands for fuel likely to be thrown upon it for the next fifty years."

Mr. Oldham.

In 1852, Mr. Oldham paid a flying visit to the place, noticed the field, and pointed out several of the errors of the previous report. He referred to the coal at Ramnuddi, opened up by Mr. Inman subsequent to the publication of Dr. McClelland's report, and says of it, "this coal is of excellent quality, it comes out in larger symmetrical masses and is freer from admixture (though still possessing the same laminar texture) than the Damoodah (Raneegunj) coals."

The favorable opinion expressed by Dr. Oldham of the quality of this coal has since been confirmed by assay. The mines are now being worked by the Bengal Coal Company. The coals of this bed and of the fine seam at Passarabhia are the best in the field. Indeed, they seem to have been accepted as a sample of the quality of the rest of the coals, and have thus, perhaps, become rather a source of error in computing the value of the field.

The next published information is contained in a report made to the Government of India, in April 1857, by Mr. David Smith, iron and coal viewer, upon the coal fields of Singrowlee and Kurhurbárí.

Mr. David Smith.

Mr. Smith commenced his remarks upon the latter by alluding to the shaft sunk upon the coal at Ramnuddi by Mr. Inman. He then notices the section exposed in the bed of the Kanko (Khakho) nuddee, and from what he states, it is evident that he considered the outcrops in the Sati and

Oopurdaha Ghats to be those of the same seams contorted and reversed in dip, and that one of them represented the bed of coal seen at Inman's shaft.

The next locality to which Mr. Smith's attention was turned, was Kúldiha, and he says:—

"The whole of this tract of land is free from faults or disturbances of any kind. The inclination of the strata is very easy, dipping north-west, and lies, in every respect, favorable for working." He adds—"But here, again, is a property possessing within itself the elements in a high degree of economic value, unproductive by the absence of a cheap communication with a market for its produce."

He does not seem to have been aware of the occurrence of the seams of coal in the Kumarsot nuddí, nor of those in the Durdurwa, north of Kúldiha, nor of the thick seams in the south-east, at Búria-dih, Chúnjka, and Khundiha.

Of the quality of the coal (referring to that of the Ramnuddi seam), he writes—"The quality of this coal is different to any I have seen in India. It is bituminous, will coke well by the ordinary mode, and is, therefore, applicable for a greater variety of purposes. It likewise ignites readily, leaving a comparatively small amount of ash of a light fawn colour."

The report concludes with the following expression of opinion as to the importance of this field:—

"Although this field cannot be, by a great deal, so extensive as that of the Damoodah (Raneegunj), the superior quality of the coal, the highly favorable condition in which it lies, with the important circumstance that the labour of 400 or 500 miners now resident in the neighbourhood may be commanded, constitute it well deserving the attention of mining speculators. All that is required is, to remove the only

disadvantage I could discover, by providing proper communication to transform the barren (and almost poverty-stricken) locality to a state of prosperity."

In the return called for by the Secretary of State for India, 1867, Dr. Oldham gives a short notice of the field; and after forcibly pointing out the absence of sound data for arriving at any satisfactory conclusion, he roughly estimates the amount of available coal, which it is likely to yield, at 168 millions of tons.

III.—General Topography.

Position of field.

The geographical position of the field is between the parallels of 86° 16′ and 86° 23′ E. long., and 24° 10′ to 24° 14′ N. lat., occupying a portion of the tract defined by the river Barákar on the south, and the Oosri, an affluent of it, on the east and north.

It is bordered in its immediate vicinity on the south, south-west, west, and north-west by hills of metamorphic rocks; but on the north, the ground is comparatively open, and the nearest hill of any magnitude is Khandauli, three miles distant.

The surface of the field is broken by the rocks of the Barákar group, which constitute Komaljore, Kheri, Bhuddúa and Bali hills, and two or three small rises in the extreme east and south-east.

Elevation.

The general elevation above the sea-level can be approximately stated at 900 feet; the ground on the north-east and south rising gently to about 60 feet higher.

Drainage.

The Sooknid river and its tributaries, the Kumarsote, the Durdurwa, the Khakho, the Suni, the Khundiha and Komaljore streams drain the entire area of the field, and pour their waters into the Barákar. The local watersheds

are so disposed that not one stream taking its rise in, or passing through the coal measures, falls into the Oosri, although that river passes the eastern edge of the field, at a distance of not more than one to two miles. The catchment basins are small; and the rivers being near their sources, none of them contain any depth of water after the cessation of the rains. The Sooknid, the Durdurwa and the Suni are very shallow, and, in ordinary seasons, dry up in January.

Jungle.

The jungle which seems to have been once very abundant is now much thinner, and it can only be said to hold its own beyond the boundary of the field. Some of the more common and familiar trees of which it is made up belong to the genera *Acacia, Buchanania, Conocarpus, Diospyrus, Ficus, Phyllanthus, Shorea, Sterculia, Terminalia and Zizyphus.*

The conformation of the ground is such that there is little cultivation of rice, the staple product of Bengal; and the proportion of tilled to untilled land is about one to six.

Inhabitants.

The inhabitants are principally Saontars, Koles,* Bhuíans, and the lower castes of Hindoos. Excellent workmen may be recruited from them, but it will require much judgment to manage them, and establish a class of miners that may be depended upon.

IV.—General Geology.

The boundaries of the field enclose a superficies of 11 square miles, the rocks of which belong to the Crystalline, Talchir and Damúda series.

The crystalline series is represented by two inliers, one upon which the village of Kurhurbárí itself is built, and another at the junction

* These Koles are not the Ooraons of Chota Nagpoor. They speak Saontari, and are the iron smelters of Eastern Hazaribagh.

of the Kumarsote and Sooknid streams, opposite Bukhshidih. The Talchirs and Damúdas, recognised easily by their special characters, are the only representatives of the unaltered sedimentary rocks. The first of these series, which is not coal-bearing, occupies only a small part of the field.

A computation of thickness of all the strata made by Dr. McClelland gave a total of 2,362 feet. Nowhere, however, does a section clear enough exist by which a calculation could be made with any accuracy of the depth of the rocks in the field; but taking their general dip, and their stratigraphical disposition, it seems improbable that the thickness of the beds is so much as this.

The rocks which occur in the close neighbourhood of the field are varieties of gneiss, bands of hornblende, quartz reefs, trap dykes and granite lodes. As these different classes of rocks have not to be specially described, they are only briefly referred to.

Hornblende rock forms a small peaky hill west of the Oosrí, and another, Chepo hill, situated to the south-west of the field. In both localities, its relations to the surrounding gneiss show it to be of the same series, inseparable from the metamorphics with which it corresponds in strike and dip.

Trap. Along the southern side of Khandauli hill, which forms a prominent feature north-east of Kurhurbárí, a trap dyke, 60 feet wide, strikes due east and west. A smaller one shows at the surface between it and the scarp of the hill. To the north of Buswasdih and about half a mile from Bhorundiha, a large rocky mass of coarsely crystalline trap occurs, forming two small rises in the clayey flat to the south-east of the field. This trap has not a very defined range, but it appears to be west-north-west to east-south-east.

Quartz Reefs are common, and form long, well marked ridges. The most prominent direction in the north is due east and west, to 15° and

20° north of west. In the east, several cross bands occur, which strike due north and south to 10° and 20° east of north. In the south the direction is from north-north-west to north-west.

Granitoid Gneiss constitutes the hill of Khandauli, and forms a broad band of country from Serampoor, in a west-north-west direction.

Granite. In the above band, several coarse porphyritic granite veins occur, whose general strike varies from north-east—south-west to east-north-east—west-south-west. They invariably cut through the strike of the gneiss, the edges of which are twisted and contorted along the veins.

V.—Talchir Series.

The Talchirs, although poorly represented as compared to the great body of Barákars, are exposed almost continuously along the different boundaries.

In the east of the field, the strata that crop to the surface are not always the most characteristic of the series. The finest development of them in this direction, is north-east of Mohlichuan, where the boulder conglomerate and the needle shales, the stamp rocks of the series, both occur. The extreme eastern extension of these beds cannot be quite accurately mapped, owing to the alluvium which commences to obscure the structure of the ground in the vicinity of the Dandidíh and Bhundarídíh road. The Durdurwa nala flows entirely through Talchir rocks until within a short distance of its confluence with the small stream east of the old coke-oven erected by the East Indian Railway Company.

Boulder conglomerate north-east of Mohlichuan.

Near the origin of the Durdurwa, a pit has been sunk. No coal has been cut, and according to all geological experience of the Talchirs, none will be found by sinking lower than has already been done. The rocks that occur where the pit has been made, are characteristic sandstones and shales of the series.

Pit sunk in Talchirs.

The Talchirs curve after crossing the Mohlichuan Nuddi, and skirting the left bank of the stream, bend eastward spreading slightly; then, double back and cross the tank south of the village.

They are very narrow from this point to Dandidíh, and in the broken ground in which the sources of the Komaljore nuddi occur, are represented by only a hard, green, ferruginous sandstone, and an occasional bed of needle shale. The bottom rocks of the series have been overlapped.

Talchirs near Dandidíh. Quartz.

Opposite Dandidíh, the Talchirs again spread out, and appear in the railway cutting south of a large quartz vein. The relation between this vein and the Talchirs, is one of natural contact. Although predisposed to accept the quartz as evidence of a fault, I was unable, in the present instance, to find any justification of such a view. I failed to find any pieces of Talchir rock mixed up with the quartz, or any other mechanical proof that a slip had taken place. The beds seen are not the lowest in the series, but the tendency of the strata to overlap accounts for what otherwise might be urged as partial evidence of a throw. The Talchirs are banked up against the quartz. They were possibly deposited on the north also, but the slope of denudation being southward, they have been removed from that side more rapidly than on the other.

It is important to thoroughly understand the relation of this quartz to the sedimentary rocks, as it settles the relative ages of the two, and bears upon the appreciation and true reading of quartz vein phenomena in other coal measure districts.

From Dandidíh southwards, along the boundary, the Talchirs do not appear continuously, the Barákars being the contact rock with the metamorphics in places. Near the mines at Buriádíh, the Talchirs are finally overlapped.

The extension of the field towards its south-east corner is too much obscured by soil to be accurately laid down. The contour of the ground however would lead one to suspect the existence of Talchirs.

Turning to the south boundary, well marked silt shales of this series occur in the flat near the Chunjka mines. A little tributary that flows into the Suni exhibits them dipping at an angle of 30° to the north-east. There is not much proof of a fault, and although, from evidence along other portions of this boundary, I am inclined to think it is faulted, it can only be so to a small extent; the occurrence of the Talchirs cropping to the surface and resting naturally on the gneiss being direct proof against any view involving a considerable amount of disturbance.

Considered economically, the absence of a large fault is to be regretted; for, with a great throw, there would have been a greater thickness of coal-bearing rocks, whereas, now, the coal exposed near the boundary appears to be the lowest that we can expect to find.

Talchirs at Domahani.

Continuing westward, the Talchirs appear near Domahani ghat, and there is a small patch of them in the Khakho Nuddi, where the boundary of the coal field turns to the north-west. The angle of dip at this point is very high.

From here to Sati ghat, the Barákars are in contact with the crystallines, but north of the ghat, there is a fine display of Talchirs.

The best ground for studying the series, however, is the Sooknid river, and the stratigraphical succession is as follows:—

At the base:—

Boulder conglomerate, the matrix of which is olive-green silt, and the boulders gneiss, schists, and quartzites.

Shales: bluish-grey, olive-green and brown, frequently nodular and occasionally calcareous.

Sandstones: thin-yellowish brown, shaly sandstones and true sandstones alternating with shales.

These beds, although well exposed, present a broken section, and cannot be measured with accuracy.

Roughly estimated, they probably do not exceed 600 feet. The boulder conglomerate, besides being seen in the Sooknid, is met with along the extreme western boundary, north of Mukpitto, and again, in the Khakho Nuddi, near Pipratand.

Boulder conglomerate.

Although the bottom bed of the series, the boulder conglomerate, as I have already shown, does not crop out continuously along the natural boundaries, but is overlapped and hidden by the higher shales and sandstones. Its thickness is never very great: within the limit of my own experience I know of only one instance in the Jherria, and another in the Karunpura fields, where the local accumulation of boulders and detrital matter, exceeds 30 feet.

Shales.

The shales are largely made up of that peculiar variety (which breaks into little needle and hatchet-shaped fragments on its weathered surface) known as the needle-shale, and which forms in every area where Talchirs are developed the 'stamp rock' of the series. On the high land of Jurbúdíh and Bukhshídíh these shales dipping at angles of 5° and 20° rest directly on the gneiss at the boundary, and conceal the boulder conglomerate. They are excellently seen in the Sooknid, and, sweeping round, constitute the main body of the series between Dhobídíh, Mukpitto and Pipratand. They are exposed in the Khakho, dipping at an angle of about 10° to the east.

Sandstones.

The sandstones, although alternating with the shales, form an horizon above them, marking the upper part of the series. They are, as a rule, fine-grained, and might be easily worked and turned to good account.

No coal in Talchirs.

Throughout the Talchirs, there is *no coal*. This absence is one of the specific characters of the series. Slightly carbonaceous shales occur very occasionally, but invariably where there is a passage into the overlying Barákars.

No additions to the fossils from the Talchír series have been obtained in this district.

VI.—Damuda Series.

Of the three groups (*a.*) Ranigunj, (*b.*) Ironstone Shales, (*c.*) Barákar, which compose the Damúda series, it is only the lower one—the Barákar—which is represented. In this respect, the Kurhurbari resembles the coal fields of Deoghur or Kuraon, and Ítkhuri, which are nearly in the same latitude.

Some fossil plants were procured by Mr. Willson at Passarabhia and Domahani, similar to those occurring in the Damúda rocks elsewhere.

Barakar group.—The Barákar group covers an area a little in excess of 8 square miles, in which are contained all the seams of coal that have been mapped. A generalised section of the rocks gives the same order of succession as in the Damúda coal fields.

At base :—

1.—Fine drab-coloured sandstones, not very unlike the underlying Talchirs.

2.—Light and dark-grey, pebbly beds, grits and sandstones.

3.—Fine and coarse whitish-grey felspathic sandstones, only pebbly in places, occurring with beds of bituminous coal.

4.—Coarse yellowish-brown and grey sandstones, with occasional bands of grey shale.

5.—Thick beds of carbonaceous shale and shaly coal, with thin irregular beds of ferruginous shaly sandstones. These latter rocks form the higher portions of the flat-topped hills.

The structure of the field is that of a basin, and the distribution of the Barákars is, on the whole, very simple, the strata, as a rule, dipping away from the boundaries. The only complication is in the ground adjacent to Mohlichuan, Passarabhia and Kúldihá.

The seams of coal are tolerably continuous throughout the area: and although they are spoken of and described anew in different places; and although they vary in thickness, their identity can be proved by the horizon at which they occur.

The boundaries are distinctly traceable everywhere except in the south-east corner of the field, where the alluvium which obscures the Talchirs, similarly conceals the extension of the Barákars.

The east boundary is throughout a natural one; the bottom grits and fine drab-coloured sandstones resting upon the exposed Talchírs, almost continuously from Mohlichuan to Buríádíh, and then eventually overlapping them.

The south boundary is slightly faulted, the maximum throw not exceeding 100 feet, even if so much, where the displacement is greatest between the Sati and Domahani ghats. Barákars form the contact rock along the whole of the southern limit of the field, except in the three spots at which Talchirs have been described as outcropping. South of Kope, the boundary runs in the bed of the Suni stream, then passing through Buniádih and keeping north of Agdoni, strikes, roughly speaking, parallel to the course of the Khakho stream.

The west boundary is natural. It crosses the Dhobídíh stream, west of the Ramnuddi dyke, and skirting the northern face of Maheshlundih hill, strikes nearly due east, then turning sharply north in the vicinity of Mahtadih, runs a short distance east of the junction of the Bayra and Kumarsote streams, and passing west of the Bayra village, joins the northern boundary.

The north boundary is formed partially by a fault, which cuts the beds transversely. The maximum throw is in the east; the beds are very much disturbed, and dip at high angles. North of Bayra, the fault leaves the field, and is apparently coincident with the run of quartz breccia which forms two to three little hills, the largest of which is about due south of Seelayah.

The disturbance, which the Barákars have undergone, although generally speaking slight, has, in the close neighbourhood of the northern fault, been considerable, and several of the dips are very high.

The axis of a synclinal passes at a distance of 11 yards south of the boundary, the beds north of it dipping to the south-west at 32° and upwards even to vertical, those to the south dipping to the north-west at angles which rapidly decrease to 35°.

An anticlinal occurs across the central part of the field, within the "surhuds" Jogitand and Kúldihá, dying out in the direction of Mahtadih and Purtdiha.

The denudation of this anticlinal ridge exposes, near Kúldihá, almost the lowest beds of the group, and the bottom seams of coal crop out in the Durdurwa.

Of the further distribution of the group, the coarse sandstones and grits are somewhat prominently developed in the Sooknid and Khakho streams, and near Maheshlundih, they form a hill south of the village, which is very conspicuous owing to its being totally devoid of any vegetation.

Shales are more common towards the middle and southern portions oi the field than in the north.

The dykes which affect the Barákars will be adverted to after the notice of the coal seams which I shall now give.

There are not more than three or at most four workable beds, and it is chiefly with a full description of these, at the different localities where they crop out, or have been already worked, that this part of the memoir will be occupied.

Commencing the notice of the seams systematically from the north-east, the first locality to describe is—

Mohlichuan.—The lowest seam of coal in the neighbourhood of this village is the one that occurs close on the right bank of the Durdurwa at its confluence with a small stream. Its original exposure has been obscured for some years, but its line of outcrop can be pretty accurately laid down by noting the strike of the rocks which are associated with it.

Where the seam was quarried by the East Indian Railway Company, its direction of dip is north-west. This, however, is not constant, and as the seam extends westwards, there are several variations. Near the bridge over the Durdurwa the dip is north. About half a mile west of this, it is between north-west and north-north-west, and north-west, and still further to the west, there is a southerly bend in the beds bringing the outcrop of the coal round with a north-west and south-east strike.

The angle of inclination varies in amount from 35° to 6° in different parts of the seam. There is a minimum of dip close to the bridge, but, as is indicated on the map, there is a rapid increase to the north.

The thickness of the seam exhibits the inconstancy which is characteristic of the Baràkar group. North of Mohlichuan it is stated to be 16′ 0″, whilst in the workings at Passarabhia it is 12′ 6″ to 14 feet.

The quality of the coal is undoubtedly good, and superior to that of any other in the field. A specimen of it raised recently is clean,

of a light specific gravity, particularly free from iron-pyrites, and the fatty laminæ preponderate, as is usual with good coal.

Passarabhia.—In the mine (5) of the East Indian Railway Company situated near the bank of the Durdurwa, the seam just referred to was cut, its thickness being 14′ 0″. Above it is a 4 feet seam, which is said to thicken rapidly in the direction of the dip to 8 and 10 feet. It also is good bituminous coal, and easily worked.

The section at No. 5 shaft, in descending series, is—

			Ft. In.	Ft. In.
	1.	Top soil and sandstone		13 0
	2. (b)	*Coal*	4 0	
Passarabhia	3.	Sandstone (conglomeratic in parts) ...		3 0
pit, No. 5*.	4. (a)	*Coal*	14 0	
	5.	Hard black shale		2 0
	6.	Hard sandstone (not cut through).		

The seam No. 2 is a most irregular bed. It crops out in the Durdurwa at the bend just below the bridge, but shows a different section to that given above, having a parting in the middle which reduces the amount of coal.

The section of No. 2 shaft illustrates very well the occurrence of this seam, which, instead of being 4 feet thick, is partly distributed through the sandstone. The sum of Nos. 2 and 3 nearly corresponds in each section.

			Ft. In.	Ft. In.
	1.	Top soil, sandstone, &c.		23 0
Passarabhia	2. (b)	*Coal*	1 0	
pit, No. 2*.	3.	Sandstone divided by a band of coal from 1′ 0″ to 2′ 0″		5 6
	4. (a)	*Coal* (instead of 14′ 0″ as above) ...	12 6	

* Sections marked with a* are from returns furnished by East Indian Railway Co. through Mr. Cockburn.

Above these seams, a thin string of coal occurs varying from a few inches to a foot. The next workable bed measuring 8 to 10 feet is higher in the series, and was cut in sinking shaft No. 40.

			Ft. In.	Ft. In.
	1.	Top soil		6 0
	2.	Coarse sandstone, lower part conglomeratic		16 0
Passarabhia pit, No. 40*.	3. (c)	*Coal* with a thin layer of shale in the middle	8 3	
	4.	Black micaceous sandstone ...		3 0
	5.	Coarse grey sandstone		15 9
	6.	Hard black shale (not cut through) ...		1 0

Where the outcrop of this seam No. 3 is seen in the tributary of the Durdurwa, the dip is north-east. This is only local, as the strata further to the north revert to the usual direction of north-west to north-north-west.

It will probably be found that this sharp twist in the bed is accompanied by some faulting and trouble in the coal.

Further to the west, this seam may be represented by a 3 feet bed cut in a well, close to the late Superintendent's bungalow.

These 3 seams of coal measuring respectively—

		Ft.	In.		Ft.	In.
a.	Lower Seam	12	6	to	16	0
b.	Middle Seam	4	0	to	10	0
c.	Upper Seam	8	3	to	10	0

are the only ones that have been opened out in the neighborhood of Passarabhia.

The prospect of working these beds profitably to the north is questionable, as the dip increases rapidly, and towards the east the strata

* Sections marked with a* are from returns furnished by East Indian Railway Co. through Mr. Cockburn.

will be influenced by the crushing in the proximity of the northern boundary. The most favorable direction is south-west of Passarabhia.

It appears from a section seen in a shaft a few paces west of pit No. 2, that there is a break in the rocks, the thick beds of coal found to the east of the break not being found anywhere to the west, although trial shafts were sunk in search of them.

The following is the section of shaft sunk near No. 2 :—

		Ft.	In.	Ft.	In.
1.	Top soil			11	0
2.	Soft sandstone			11	0
3.	*Coal*	0	6		
4.	Hard sandstone			11	6
5.	Blue shale with thin layer of coal			3	8
6.	Hard sandstone			2	4
7.	*Coal*	1	6		
8.	Hard sandstone			6	6
9.	*Coal*	1	3		
10.	Hard sandstone			11	3
11.	*Coal*	1	6		

It has before been stated that the rocks turn round and change their strike near Kuldiha. It is therefore not improbable that the break is connected with this change of strike, and the opposing dip of the west boundary.

Bhundaridih.—South-east of Bhundaridih (a village outside the limit of the field), a pit has lately* been sunk 10 yards from the boundary. In it, the rocks are seen dipping at 32° south-west, and two beds of coal had been struck when I visited it. Both the beds were so saturated with water that I could not judge of the quality of the coal.

South of the pit and just north of the railway, the axis of the synclinal previously referred to passes, so that whatever the quality of coal may be the circumstance of its position renders it of scarcely any value.

* November 1868, by the Equitable Coal Co.

Jogitand nullah.—In this nullah which flows east of Jogitand, there are two outcrops of coal, but so obscure are they, a foot or so only of thickness being exposed, that I can do no more than indicate their occurrence. Passing eastward and southward of Kuldiha, there is a great deal of broken ground through which the head-waters of the Komaljore nuddi flow. Felspathic grits and sandstones are strongly represented, but there is no sign at the surface of the thick seams worked more to the north at Passarabhia. Two thin beds of coal and one of stony coal occur which are indicated on the map.

Purtdiha nullah.—In the Purtdiha nullah, however, there is an inferior coal seam determined to be 10′ 4″ thick by a shaft sunk on the left bank, which is very possibly the representative of one of the larger beds. The section is—

		Ft. In.	Ft. In.
	1. Top soil		5 8
	2. *Coal*, inferior	7 0	
Purtdiha, No. 42.*	Hard black shale	0 8	
	Coal, shaly	2 8	
	3. Hard black shale		2 0
	4. Blue sandy shale (not cut through).		

The roof of this seam consists of coarse grey shingly conglomerate, precisely similar to the rock which, in parts, forms the roof to the 14 feet seam of coal at Passarabhia. In both localities, the coal rests upon 2 feet of black shale.

Further down the river, another seam of coal occurs, averaging about 3 feet in thickness. It lies east and a little north of the village of Purtdiha and dips at an angle of 5° to the south-west.

Its section at the outcrop is—

	Ft. In.	Ft. In.
1. Top soil		3 0
2. *Coal*	3 0	
3. Sandstone (not cut through).		

Two other sections to the north of this, where the above was obtained, illustrate the irregularity of the seam.

		Ft.	In.
1.	Top soil	7	6
2.	Soft sandstone ...	2	0
3.	Soft shale	1	4
4.	*Coal*	0	8
	Sandstone	1	8
	Coal	0	7
5.	Hard sandstone (not cut through) ...	14	9

	Purtdiha, No. 31A*	Ft.	In.
1.	Top soil	5	0
2.	Sandstone	5	0
3.	*Coal*	1	0
	Blue shale	5	0
	Coal	2	6
4.	Sandstone (not cut through) ...	16	0

This seam is very probably the one which crops out in the Puthrodiha nullah south-east of the village, and shows an almost identical section. There is a reduction in the thickness of the shale, and a gain in coal, but the aggregate of the essential parts of the section is the same.

There are no workable seams higher in the series in the Purtdiha nullah. The general strike in this portion of the area is nearly due north-west, and the strata are made up chiefly of alternations of thin sandstones and shales with occasional small beds of coal averaging 10 to 14 inches. The nature of the section in the Komaljore nuddi is somewhat similar.

Puthrodiha nullah.—At the head of this river are the old mines of the East Indian Railway Company at Búríadíh, in which two seams were formerly worked. The lowest bed is 14 feet thick, the upper 9′ 6″. They strike nearly due north-west and dip at 12° to the south-west.

The bottom bed was cut through in shaft No. 12.

			Ft.	In.
Booreeadeeh,	1.	Top soil	1	6
No. 12*	2.	Sandstone	10	0
	3.	*Coal*	14	0
	4.	Shale (not cut through)	11	0

The upper bed was cut in No. 32 shaft.

			Ft.	In.
Booreeadeeh, No. 32*	1.	Top soil	4	3
	2.	*Coal*	9	6
	3.	Black highly carbonaceous shale (not cut through)	4	6

The quality of this coal is said to be good, but an assay of it gave as much as 10·7 per cent. of ash; a light line of rail is being laid down to the pits, which will give them an advantage in carriage when they are re-opened.

To the north-west of the mines, not far from the boundary, there is a carbonaceous outcrop, but when sunk into it does not appear to have turned out of any value. The strata, however, near the edge of the field, follow the curvings of the boundary which are very rapid here, and trustworthy results will only be obtained by exploration further west, where the rocks have a steady strike, and are free from local contortions.

Higher in order of succession than the two seams at Búríadíh, is the one south-east of Puthrodiha dipping at 5° to south by west.

Its section in a trial shaft was almost identical with that of the 3 feet seam of the Purtdìha nullah.

		Ft.	In.
1.	Soft sandstone	9	6
2.	Black coaly shale	1	0
3.	Hard sandstone	1	0
4.	*Coal*	1	6
	Hard shale	3	0
	Coal	3	6
5.	Shaly sandstone (not cut through)	9	2

No coal is seen further down the river, a steady succession of the felspathic sandstones, and shales occurring as far as the junction of the Puthrodiha nullah with the Purtdiha.

Chúnjka.—A mine is situated on the north side of the Suni nuddi, close to its junction with a smaller stream flowing from the south.

Two seams of coal were worked here, the lowest of which is 11 to 14 feet thick, the upper 6 feet. They strike about 25° north of west, and dip to the north-east at an angle of 15°. They are both of average quality, but some of the coal is stated to be as good as that raised at Mohlichuan.

The upper seam was cut by a shaft situated about a hundred paces north of the mine. The section is as follows :—

			Ft.	In.
	1.	Top soil	9	0
	2.	Coarse soft sandstone	24	0
Choonjka,	3.	*Coal*	6	0
No. 16*.	4.	Shale	1	0
	5.	Hard grey sandstone	8	0
	6.	Grey sandstone (not cut through)	9	0

South-east of the above locality, the lower bed was cut in another shaft. Its thickness here is 14 feet, but elsewhere it is 11 feet, some of the coal being replaced by sandstone.

			Ft.	In.
	1.	Top soil	5	0
Choonjka,	2.	Soft sandstone	5	0
No. 26.*	3.	*Coal* (good)	14	0
	4.	Black shale	2	0
	5.	Grey sandstone (not cut through)	9	0

If the section of this shaft be compared with those at Passarabhia, it will be seen that there is a similarity in one or two points between them.

The lower bed of coal at Passarabhia is of the same thickness as that at Chunjka; and in both localities the coal rests upon 2 feet of black shale with sandstone underneath.

Khundiha.—To the south of the village of Khundiha, and below the junction of the Purtdiha and Puthrodiha nullahs, there is a bed of inferior coal of some thickness with a thin seam above it. The section,

which, in some respects, corresponds with that at the Domaháni mine, two miles and a half to the west, is as follows:—

		Ft.	In.
1.	Top soil	8	0
2.	Sandstone	6	3
3.	*Coal*, inferior, with bands of shale	11	3
4.	Black shale gradually becoming sandy	8	3
5.	Hard grey sandstone (not cut through).		

Where the seam crops out in the river, the dip is distinctly to the west. A large dyke cuts it near the confluence of the two rivers and a smaller one to the south belonging to the micaceous type of traps.

The coal at this locality was never worked, owing to the discovery, shortly after it was cut into, of the better seams at Chunjka.

South-west of Khundiha, and a short distance from the village, two thick beds of shaly coal were cut in a trial shaft. The following was the section:—

			Ft.	In.
	1.	Top soil and sandstone	6	0
	2.	*Coal*, inferior, with bands of shale	13	0
	3.	Shale	1	0
Khundiha Hill,	4.	*Coal*, inferior	6	8
No. 25.*	5.	Black micaceous shale	1	0
	6.	Hard sandstone	15	0
	7.	Hard shaly coal (not cut through)	1	0

These beds are nearly horizontal. None of these seams are worth working, the quality of the coal being too bad.

Kope.—At Kope, a bed of coal crops out in the nuddi, a little north of its confluence with the Suni. It dips to the north, but the axis of a synclinal passes very close to it, so that it will be found difficult to work where the present pits are sunk, and the area over which it occurs will be small. It may, I think, be looked upon as almost useless. The quality of the coal is also poor. It would appear, indeed, as if there were a decided deterioration in the quality of the seams in the southern part of the field as compared with those in the north.

Above this seam, a damaged bed of coal was struck near a large dyke, probably the continuation of the one that occurs south of the confluence of the Purtdiha and Puthrodiha nullahs. The section in the trial shaft was:—

		Ft.	In.
	1. Top soil	6	6
Kope,	2. Damaged *coal*	4	6
No. 33.*	3. Soft black shale	2	0
	4. Hard sandstone	9	6
	6. Black shale	11	0

Komaljore nuddi.—As before stated, nothing is seen of the thick beds of coal in the ground where this river takes its rise. In passing southwards down the valley of the stream, we find thick-bedded friable sandstones with thin beds of shale and shaly coal. These rocks have, on the whole, a slight south and south-easterly inclination, but in many places they are horizontal. A reverse northerly dip with a decided angle is well seen near the boundary, but a corresponding thickness of beds, after allowing for the throw of the southern fault is not exposed. There is probably an overlap of some of the strata,—a phenomenon of no uncommon occurrence in the Barákar group.

No workable beds of coal crop out in the banks of the main river or its feeders; but if trial shafts of sufficient depth were sunk, I have little doubt that the representatives of the thick seams would be met with. A shallow pit north of Buniadih was sunk down to 50 feet, but only sandstone was cut. The section was:—

		Ft.	In.
	1. Top soil	5	0
Buniadih, No. 29.*	2. Soft grey and brown sandstone with streaks of iron	30	0
	3. Hard grey sandstone	15	0
	Total ...	50	0

Khakho nuddi. (A.) *Domahani ghát.*—At the confluence of the Khakho and Sooknid rivers there are two seams of coal, the lowest of

which is 9 feet, and the upper 2 feet 6 inches dipping 10° to the north. A shaft was sunk on the east side of the Sooknid to work them, and the section was :—

			Ft.	In.
Domahanee, No. 14*	1.	Top soil	8	0
	2.	Sandstone	34	0
	3.	*Coal,* shaly	2	6
	4.	Hard black shale	8	6
	5.	Sandstone	13	6
	6.	*Coal,* good	9	0

The quality of the coal of the lower seam is stated to be good, but it varies. The upper seam is said to yield tolerably good coal.

The out-crop of the bottom seam is visible in the Khakho. It is affected a good deal by trap,* but as much of the coal as is free, looks of fair quality. Columnar structure has been induced in the coal, and capital specimens of this can be procured from the bed of the river.

(B.) *Oopurdaha ghât.*—At Oopurdaha ghât three seams occur, and from thence their outcrops are partially seen to extend as far as Sati ghât.

The lowest seam is exposed where the road from Kurhurbárí crosses. Its dip is 11° to north-north-west and the horizontal extension of its out-crop measured at right angles to its strike is 42 feet, making the seam by calculation a little over 8 feet in thickness. The quality of the coal seems poor.

The other two beds are seen closer to the top of the bend of the stream, showing an increased angle of inclination owing to the contraction

* In a shaft report, furnished by the East Indian Railway Company to the Survey, through Mr. Cockburn, this trap is stated to have caused great inconvenience in mining the coal.

It may be well to state, that in quoting the returns of these sinkings by the East Indian Railway Company, the spelling of the names adopted by them has been retained.

at the elbow of the boundary north of Gappoi. They change their direction of dip to north-north-east, and then to north-east, a little higher up the river.

Where the patch of Talchirs occurs, a small bed of coaly shale is exposed, lower in the series than either of the other three.

None of the seams, excepting the 8-feet one, appear to be worth working.

(C.) *Lopsadih ghât.*—Two outcrops, the continuation of those just referred to, are visible. The 8-feet seam is well exposed in the bed of the stream, and the one above it in the left bank. They dip at an angle of about 15°.

An old shaft exists west of the river, but it can be of little use, as it is placed too near the boundary.

(D.) *Sati ghât.*—At this ghât the same seams again occur. The lowest is the thin bed seen at Oopurdaha near the Talchirs. In this place it is partially affected by trap.

Above it is the 8-feet bed, which here measures 8′ 9″, and dips nearly due east, at a high angle. The coal is inferior, and is thickly studded with incrustations of iron pyrites. It will probably be freer, when cut into, some distance.

The next seam in ascending order also yields coal of an inferior quality. It is apparently not more than 4 to 5 feet thick including the partings of shale. A fourth bed is very indistinctly seen in the left bank of the Khakho, but is more clearly exposed in a small tributary flowing from the east.

Mukpitto nullah.—The extensions of two of the above seams are seen in the Mukpitto river; and the present Manager* of the Bengal Coal Company is engaged in testing their thicknesses by means of a

* Mr. Heyne.

bore hole on the left bank of the stream. The strike of these beds will be found to change inland of Sati ghât, keeping more or less parallel with the curve of the boundary.

Ramnuddi.—Two seams occur here, but only the lower one is workable. The section is :—

		Ft.	In.
1.	Top soil, &c.	3	0
2.	*Coal*	1	4
3.	Sandstone...	15	0
4.	*Coal* ... ... 9 0 to	11	0
5.	Sandstone		

The larger of the above seams was the bed worked by Mr. Inman to some extent in 1851-52, and was the first coal which was systematically mined in the field. It is seen out-cropping in the bed of a small stream close to Mr. Inman's shaft, and is about 3′ 6″ at the surface. It, however, increases rapidly, as the above section shows, to 9 and 11 feet. The dip is 10° to the south-east. The Bengal Coal Company are now driving galleries and raising coal which is of good quality, and little inferior to that of the Mohlichuan seam, which they are working in their Kuldiha property.

A fault occurs near the mouth of the shaft striking north-west—south-east with a down throw to the west. This seam would appear to be affected by more than one fault, as search was made for it in the direction of the dip by the East Indian Railway Company, who own the adjoining ground, but without success. It is possible, however, that the borings may not have been carried down to a sufficient depth, too small an angle having been allowed for the inclination of the rocks. This is a fruitful source of discrepancy between calculated and *actual* depths, and although it can only be guarded against by care, the error should be avoided by making rather an excessive than a deficient allowance for dip.

The seam as a property suffers seriously from the existence of the large dyke to the west of the shaft; otherwise, the goodness of its coal renders it valuable.

Ramnuddi nullah.—In this stream, a bed of shaly coal was cut 1' 6" thick, at about 15 feet from the surface.

Bali Hill. *—A thick bed of inferior coal is partially seen outcropping on the north escarpment of the largest hill of the Bali group. The following section was cut in sinking a shaft above the escarpment:—

		Ft.	In.
1.	Top soil and coarse broken sandstone	3	0
2.	*Coal,* shaly and inferior	24	0
3.	Soft, fine, grained sandstone	2	0
4.	Shale	0	6
5.	Brown, coarse-grained sandstone	10	0
6.	Hard grey sandstone (not cut through)	12	0

This coal is of inferior quality, and resembles the useless seams (of which it is probably the representative), that were found in the Bhuddua and Komaljore group of hills.

The only locality that now remains to be described, in which outcrops of coal have been discovered, is the Koomarsote river and its tributaries.

Koomarsote nuddi.—The lowest seam exposed is separated by a small thickness of grey felspathic sandstone, and fine arenaceous shales from the Talchirs. The section at its out-crop gives about 2 feet of inferior coal. The dip is east-north-east. Higher up the stream, the dip changes to north-east and eventually to north.

* This hill is, I believe erroneously, termed Jatakuti or Jakuti hill. From enquiries which I made Jatakuti would appear to be west and not east of the Khakho nuddi.

The next seam is a shaly coal of 3′ 0″, with shale above and below it.

About 12 feet of sandstone separates this from another bed which is only partially exposed in the rivulet. It had been cut into by the East Indian Railway Company, and is stated to be a hard, stony coal, and not worth working. The thickness is 4 feet, and its dip is 10° to the N.

A thin bed about 7″ to 8″ occurs above this near the faulted boundary; a thin band of shaly coal, 18 inches thick, with coarse grey and brownish sandstones, exhibiting a reverse dip to south by east, was visible in 1859.

None of these seams either from their thickness or quality judged by the evidence at their out-crop, are worth consideration; but, before condemning them, it would be well if the proprietors in whose land they occur, tested, by borings and trial shafts, their behaviour under ground.

Being, as these seams are, the representatives of the thick beds of coal met with elsewhere, they may possibly increase to a workable thickness along other portions of their strike. The probability, however, is against their doing so, as the rocks associated with them show a tendency to thin out in the direction of Bayra, and the out-crops of carbonaceous shale also exhibit a diminished thickness.

Bayra nullah.—Two out-crops of black shale are seen, dipping 10°. They occur on the strike of the Kumarsote seams.

All the places at which coal crops to the surface, or has been discovered by the sinking of bore-holes or shafts, have now been noticed. The conclusions which may be drawn from the information contained in the preceding pages, I have reserved for the summary at the end of this memoir.

VII.—Trap Dykes.

Trap dykes occur in great frequency, and, of course, will have impaired the coal through which they pass. With the exception of two, which are micaceous traps, the others are diorites and compact felspathic traps.

They appear to be of one age, and the direction which they pursue seems no evidence of prior or subsequent injection.

There are altogether 15 dykes. Many more will undoubtedly be met with in the workings; and of those seen at the surface, ramifications will probably occur in the coal.

Classified there are:—

Dioritic traps	...	... 4	
Compact felspathic traps		... 9	three of which are obscure.
Micaceous traps	...	... 2	one obscure.

Enumerating them from the east westwards.

1. *f.*—*Course nearly north and south. It crosses the small tributary of the Durdurwa flowing from the Equitable Coal Compay's pit. The seam affected by it will be the 14 feet Mohlichuan seam.

2. *f.*—Course somewhat north of east. It occurs north of Mohlichuan and south of the Durdurwa. The coal in the Kúldiha mines will be affected.

3. *f.*—Course irregular. It crosses the small stream in which the outcrop of the third seam at Passarabhia is seen, then heads for the tank west of the railway bungalows. This will affect the bottom and middle seams at Passarabhia.

4. *f.*—Course nearly due east and west. It is seen on the north side of the Durdurwa not far from the bridge. It affects the same seams as the preceding dyke.

5. *f.*—Course approximately east and west. It may be distinguished as the Jogitand dyke, as it passes close to that village. Its average thickness is about 3 feet.

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* The letters indicate the type of trap. *d*=dioritic trap. *f*=felspathic trap. *m*=micaceous trap.

6.—Course indeterminate. This dyke occurs close to the coal mine at Buriadih, and extends from the gneiss on the east, to the coal measures on the west.

7. *d.*—Course nearly south-east to north-west. It varies, however, along portions of its outcrop. This large dyke crosses the Suni river west of Chunjka, cuts the thick seam below the confluence of the Purtdiha and Puthrodiha nullahs, and passes about 2 yards north of pit 33 at Kope. It is visible west of the Komaljore nuddee, but does not appear to extend much beyond Buniádih.

8. *m.*—Course indeterminate. This is a small dyke which affects the coal south of Khundiha.

9. *d.*—Komaljor nuddi dyke, which is 40 feet broad, in places has an approximately north-north-east course. It shows several times in the channel of the river, and affects all the seams in the neighbourhood. It extends in both directions beyond the boundaries of the field.

10.—Fragments of trap are strewn over the ground at the bottom of Bhuddua hill, north of Agdoni.

11.—This dyke occurs in the bottom seam of coal at the Domahani Ghat.

12. *d.*—Ramnuddi dyke. This is extremely well seen, and is of large size. It is traceable from the Khakho river, to the west of Inman's shaft, and from there, between the two 'tolehs' of Dhobidih, and into the crystallines through the Talchirs.

13.—The lowest of the seams in the first bend of the Khakho below Satí Ghat is altered by trap.

14.—Course nearly north-west and south-east. This dyke is north of Manuktand, and is seen in the gneiss beyond the field.

15. *f.*—A small dyke, with a north-west strike, occurs near Kope.

VIII.—Economic Summary.

An analysis of the information which has been gathered tends, I think, to prove that the capacity of this field, as a coal producing locality, depends upon the extent to which its lower seams are developed, and

as the boundaries of the field have now been determined with sufficient nicety to calculate the area of the Barákar group, we might, did these seams overlie each other continuously, readily estimate the amount of coal which existed.

Accepting the thickness of the three seams at Passarabhia as 32 feet, and the area of the Barákars as 8½ square miles, they would contain about 2,720 millions of tons.

I have, however, already pointed out that the principal seams exhibit an irregularity in their sections—a characteristic of the Barakar group wherever it is developed.

Examining this point more in detail, we find that at Passarabhia there is an excessive accumulation of carbonaceous matter which diminishes in every direction from that spot, at Buriadih, at Chunjka, at Kope, at Domahani, Oopurdahá, Lopsadih and Satí ghats, at Ramnuddi and in the Koomarsote nuddi. In all the localities enumerated above, although at some places the seams have become so reduced, and the aspect of their sections so changed, that it is difficult to correlate them, still the general horizon at which they occur in the series shows that we have seams representative of the beds at Passarabhia.

The following table gives a ready idea of the thickness of these seams in various parts of the field:—

		Ft.	In.
1.	Passarabhia, 3 seams	32	0
2.	Buriadih, 2 seams	23	6
3.	Chunjka, 2 seams	17	0
4.	Domahani, 2 seams	11	6
5.	Oopurdahá, 3 seams (uncertain), about ...	15	0
6.	Lopsadih, 2 seams " " ...	13	0
7.	Satí ghat, 3 seams " " ...	15	0
8.	Ramnuddi, 2 seams " " ...	12	6
9.	Kumarsote nuddi, 3 seams, about	9	0

Taking the average of the above table as 16 feet, and multiplying by 8½ square miles, we reduce the amount of coal to 1,360 millions of tons.

If we wish however to arrive at an estimate of the available coal, we have to consider collectively the size of the seam, the dip, the quality of the coal, and the effect of faults, dykes, and other troubles.

This next table gives the thicknesses of the coals at every place mentioned in the memoir, and by excluding the non-workable seams we shall be able to judge fairly what the field may be reasonably expected to yield.

Locality.	No. of seams.	Thickness in descending order.	Workable thickness.	Remarks.
		Ft. Inc.	Ft. Inc.	
Bhundaridih	2	4 0 10 0	......	The dip of these seams is too high for working economically. The thickness of the 10' 0" seam is stated approximately.
Mohlichuan	2	4 0 16 0	20 0	
Passarabhia	3	8 0 8 0 12 0	28 0	These thicknesses are averages, and are fairer estimates than assuming the greatest thickness of each seam.
Kuldiha	2	4 0 14 0	18 0	Average thickness.
Purtdiha nullah	2	3 0 7 0	......	Both these seams are too inferior in quality to pay for working.
Puthrodiha nullah	3	3 0 9 6 14 0	23 6	The upper seam is too small. The two lower are worked at Buriadih.
Chunjka	2	6 0 11 0	17 0	The bottom thickness is an average.
Khundiha	2	1 0 11 3	......	The upper seam is approximately given. Both these beds are of too poor a quality to be regarded as available.
Khundiha Hill	2	13 0 6 8	......	Not available owing to badness of their coal.
Kope	2	4 6 8 0	......	Eight feet is approximate. Both seams inferior.
Komaljor nuddi	...	......	......	All the seams are too small.

Locality.	No. of seams.	Thickness in descending order.	Workable thickness.	Remarks.
		Ft. Inc.	Ft. Inc.	
Domahani Ghat	2	2 6 9 0	9 0	Only the lower seam is available; the thickness of the upper being too small for working.
Oopurdahá Ghat	3	3 0 4 0 8 0	8 0	The two upper beds are not clearly seen, and thicknesses are assumed. The lower seam is the only one available, and it is of inferior quality.
Lopsádih Ghat	2	4 0 8 9	12 0	A small seam higher than either of these two will probably be found nearer Bali Hill: but the only bed available is the 8′ 0″ seam.
Sati Ghat	4	2 0 4 0 8 9 1 0	12 0	The only ascertained thickness is that of the 3rd seam. At its outcrop in the Khakho, it is strongly spotted with iron pyrites.
Ramnuddi	2	1 4 11 0	11 0	
Bali Hill, Bhuddus Hill, Komaljore Hill	...	24 0	......	This seam is scarcely more than carbonaceous shale.
Kumarsote nuddi	3	4 0 3 0 2 0	......	All these are inferior seams of coal.

I exclude as unavailable all seams under four feet, and those the quality of whose coal would render them unprofitable.

We thus see that over a very large section of the field, the available thickness is only nine, twelve, and 17 feet, and that such ground as that in the extreme north-east—near Mahtadih and north of the Komaljore Nuddee,—may be looked upon as practically barren.

The coals at Oopurdaha, Lopsadih and Sati ghats, are also of an inferior quality, being shaly and strongly impregnated by iron pyrites.

Fifteen feet of coal over the whole field, I should consider as not being too small an average. And deducting $\frac{1}{8}$ of the total area for barren ground, and where the overlying rocks are too thick to work the coal profitably, we have $7 \times 15 = 105$ millions of tons. From which, subtracting one-third for waste and loss by intrusion of trap, &c., 80 millions of tons remain as the probable available amount.

The quality of the Kurhurbárí coal has been tested by several assays. The specimens which gave the best results were obtained from localities in the east of the field, where the coal is of better quality than it is in the south-west:—

Locality.	Fixed carbon.	Volatile matter.	Ash.	Remarks.
Mohlichuan	64·9	24·8	10·3	
Ditto	68·6	24·8	6·6	
Ditto	73·1	22·1	4·8	This was probably a picked specimen.
Passarabhia	68·5	19·0	12·5	
Buriadih	66·3	23·0	10·7	
Chunjka	67·2	24·0	8·8	
Bali*	50·9	15·1	34·0	
Ditto	48·2	12·6	39·2	
Khundiha	57·1	16·4	26·5	
Ramnuddi	69·8	23·4	8·8	Caking coals.
Kuldiha	71·8	24·0	4·2	Caking coals.

The better seams represent a superior working duty to that of the coals of the Ranigunj district. The experiments, continued over 3 months on the East Indian Railway, proved clearly that the coals raised in the Kurhurbárí field were better than those obtained from the Ranigunj field. Since these trials were made other seams have been opened out in the Ranigunj field, such as Sitarampur, Sanktoria, &c., which are much more nearly equal, if not quite equal, to the Kurhurbárí

* Written Jutkutti in the "Coal Resources of India."

coals. But so far as the trials went the results shewed that the coals worked in the Kurhurbárí field were superior to those obtained from the Ranigunj field, in the ratio of 113 to 100.

The principal advantage possessed by the Kurhurbárí field is one of position as a supplying area for up-country and the stations west of Lukki Serai, there being a saving of 23 miles of carriage as compared with the Ranigunj field. But this must be considered in connection with the available amount of coal, and the financial problem :—Will the saving in carriage over Ranigunj coals give a profit upon the expenses of railway construction, and price of lands? still remains open to discussion.

If the rate of consumption be assumed at 250,000 tons a year, the Kurhurbárí field has a life of about 300 years.

IX.—History of the Coal Field.

This coal field was first brought to notice by Dr. McClelland in 1848, and some coal was raised at the outcrop of several of the seams to test their excellence. Systematic working however was initiated by Mr. Inman in 1851, who mined the bottom seam of coal at Ramnuddi. This coal was all carted to the Ganges.

Messrs. Ward and Co., railway contractors at Monghyr in 1855 held Kúldiha and Ramnuddi, which Mr. Inman formerly possessed.

In 1856-57, the interest in these two localities was transferred to the Bengal Coal Company, who now possess in addition holdings at Dhobidih, Mukpitto, Sati ghat, Oopurdaha ghat, Domahani ghat and Bayra. The most valuable part of their property is that west of Kuldiha, and mining operations in this direction are being vigorously prosecuted. The Ramnuddi property is small, but it yields good coal, only a little inferior to that at Kuldiha. In 1862 the working of the

coal field ceased entirely, but in May of 1868, the Bengal Coal Company re-opened Ramnuddi, and has already raised in anticipation of the opening of the 'chord line' of railway, a large supply of coal. In 1859, Mr. T. F. Cockburn, one of the East Indian Railway Company's resident Engineers, was appointed superintendent of their mining property at Kurhurbráí. Workings were advanced with great vigour subsequent to his arrival, and a very large amount of coal was carted annually to Lukki Serai, but previously to 1863, all such operations were suspended. The property has since, we believe, been purchased by Government, but as yet no movement has been made towards re-opening their mines.

HAZARIBAGH.
December, 1868.

Hughes. Deoghur Coal Fields

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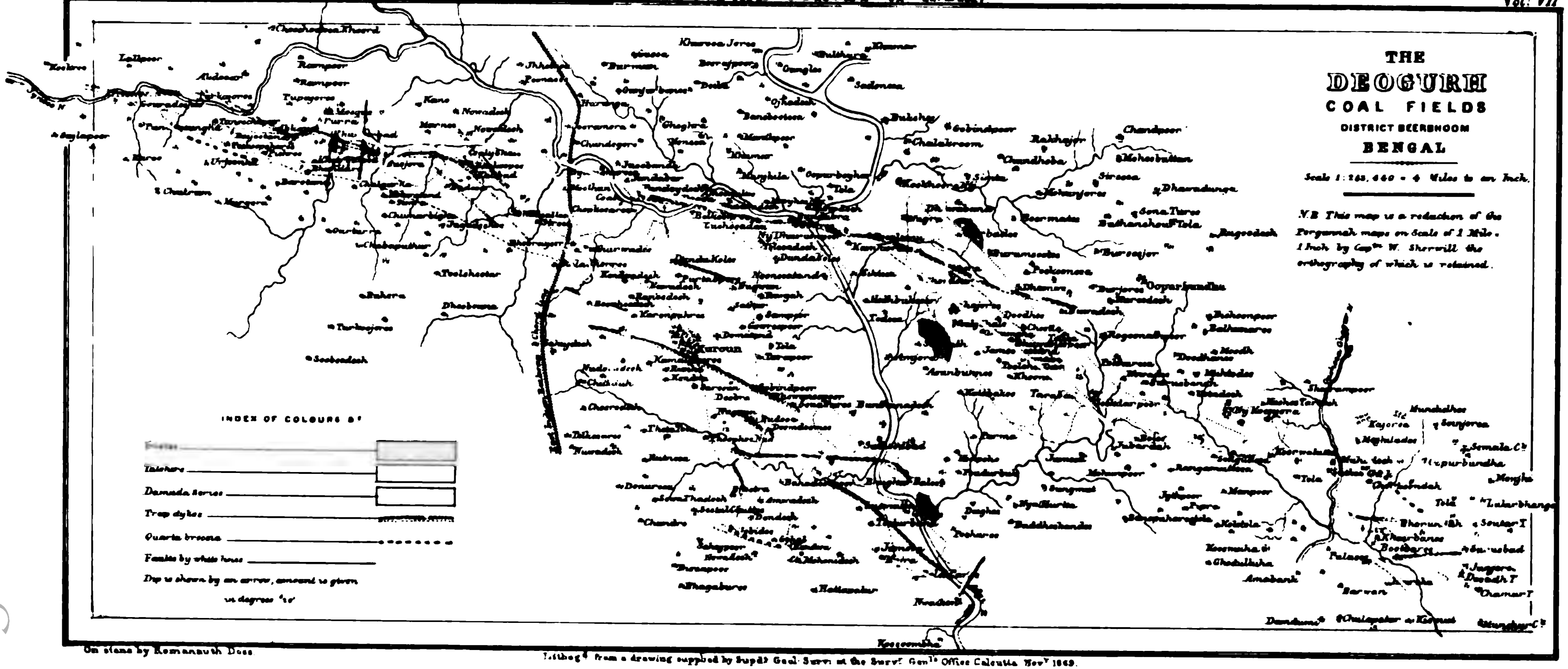

On stone by Romanauth Doss

Lithog. from a drawing supplied by Supdt. Geol. Survy. at the Survr. Genl's Office Calcutta Novr. 1869.

The DEOGHUR COAL FIELDS, *by* THEO. W. H. HUGHES, F. G. S., *Associate Royal School of Mines, Geological Survey of India.*

The opening up of the country north of Ranigunj by the chord-line of the East Indian Railway, has brought into some prominence the outlying coal measures in the neighbourhood of the Adjai river, situate in the Sonthal Pergunnahs, and to the east of the Kurhurbárí coal-field which is in the Hazaribagh District.

The Geological Survey in 1853 first demonstrated the existence of these coal measures; but owing to the poor prospect of any of the areas yielding coal of such quality as to make them profitable centres of mining enterprise, they were not considered of much importance.

The increased facility of communication with Calcutta and the provincial towns afforded by the construction of the line of Railway from Sítarampur to Lakki Serai, suggested the possibility of advantageously working the coal; and, in May 1867, Mr. Sandys of Bhagulpur issued a prospectus, in which he explained the position and the quality of the coal, and pointed out the facilities that existed for its transport. The position of the coal-field, he thinks, "will naturally command the market for coal in the north-western direction when both chord and loop line work together," and he has "little doubt that in a few years, all the coal that can be raised in such a position, whether east or west of the chord-line, will be in full demand."

With these sanguine views of Mr. Sandys, we are unable to coincide; an examination of the rocks having proved that, however favorable the position of the outliers, they will never be of much importance owing to

the poor quality of the coal they contain, and the limited area over which it occurs, so that no successful competition with the Kurhurbárí field even locally can be initiated for years to come, in fact, not until the almost total exhaustion of the resources of the latter.

The coal which is found at Sahajori was assayed by Dr. Waldie of Barnagore, and contained 28 to 37 per cent. of ash. I believe it to be an average sample of the coals occurring in the three outliers, with the possible exception of one in the smaller outlier lying to the east of the Adjai.

The evidence bearing out the opinion which I have expressed of the present comparative uselessness of these outliers will be fully detailed in the following pages, after first touching upon their physical features and their geological structure.

II.—Physical Features.

These outliers lie between Long. 86° 37′ and 87° 5′ E. and Lat. 24° 5′ and 24° 15′ N. in the level ground north of the valley of the Barákar river, and south of the broken ranges of hills of which Puturdha, Phuljori, Sonatarí and Gumrie are some of the highest points.

Within the boundary of the sedimentary rocks there are no hills, and the surface of the country is scarcely undulating except in the immediate vicinity of the rivers. The large proportion of the area covered by the Talchirs tends to stamp this deadness of character upon the whole of the outliers, which is in contrast to the Kurhurbárí field where there is a preponderating influence of the Barákars.

The drainage is principally into the Adjai, which, taking a southerly course after its junction with the Jaintí, passes between the two larger outliers, and then turns eastward to flow through the north-easterly portion of the Ranigunj field.

The height of the general surface above the sea taken at a point in the same longitude coincides nearly with that of the larger fields in the valley of the Damúda. This fact is important in its bearing on the enquiry as to how far the old surface of deposition has been altered, by faulting, subsequently to the formation of the rocks.

There is but little jungle, and that is too thin to afford permanent shelter for any larger animals than jackals, foxes, and a few small rodents. The hills however surrounding the fields are well wooded, and are the favorite resort of those formidable man-eating tigers which have made Deoghur notorious in the sporting annals of India.

III.—Geological Structure of the Outliers.

These small spreads of coal measures I have termed outliers with reference to the main body which extends up the valley of the Damúda constituting the Ranigunj, Jherria, Bokaro, Ramgurh, and Karanpúra fields. Another outlier, is the Kurhurbárí field; and within the limits, or nearly so, of latitude which I have given above, there are other small areas of Talchir and Damuda rocks besides those which I am about to describe under the name of the Deoghur fields.

I have retained Deoghur as a general title for the three outliers, although each may be referred to by a special name. The town of Deoghur (Baijnath or Bajinath) is a well-known resort of Hindu pilgrims, and formerly gave its name to that part of the district in which the outliers occur, all of which is now included as a portion of the Sonthal Pergunnahs.

A. *The* Jaintí *Coal-field*.—Describing the outliers, of which there are three, in the order of their size, the first one with which we have to deal is that west of the Adjai, and which I propose to call "*The* Jaintí

coal-field" from the river of that name which traverses a part of the field. It covers an area of 24 square miles; and both the Talchir and Damuda series are represented, the latter by the Barákar group only.

1. *Talchir series.*—This series covers the greater part of the field, and is chiefly represented by the silt shales which are so prominently developed in the Jherria District. Amongst the best sections are those of the Puphi Nuddi, the Purtal, and the Busjora which expose the conglomerate bed at the bottom, and the usual succession of silts, shales, and sandstones. There is no special feature to allude to which has not already been amply described in my previous reports and contributions to the Memoirs of the Survey, and, merely alluding to the local distribution of the series and the faulting of the boundaries, I will pass on to the more important, though not more interesting, deposits of the Damuda series.

The conglomerate bed contains boulders equal in size to any which I have elsewhere seen, with the exception of those in the Bokaro field. It is found along the non-faulted boundaries; and evidences of it beyond the outlier are met with in the loose pebbles and boulders scattered over the surface of the gneiss.

Purple shales are to be seen north of the Puphi Nuddi, and south of Nugwan, dipping south-west at variable angles. They occur also near Belkiari, not far from the small inlier of gneiss.

The boundaries of the Talchirs are variable. The main southern one is natural, notwithstanding that the quartz-breccia in the gneiss opposite Pichri and the Sonthal village of Tikupahari suggests the probability of a fault. The lowest beds of the series are found almost everywhere along the boundary, dipping at small angles towards the middle of the field, and there is not the slightest evidence of a throw. The most distinct faults are, the one south of Jobidih, and the one

north of Belkiari. Both of these belong to the series of east and west faults which play an important part in determining the contour of our larger fields. The Belkiari fault is cut off to the west by the Busjori fault, and to the east it appears to cross the Adjai, and be connected with the fault which throws the Barákars of the Sahajori coal-field.

2. *Damuda series, Barákar group.*—Of this, the most important group, I am sorry to say that it scarcely covers an area of 5 square miles; and that its economic value, even with all the advantages of a line of railway running directly through it, is scarcely worth consideration.

There are two independent areas of Barákars: a smaller one in which Mr. Sandys sank some shallow pits on the banks of the Bogroro river—and a larger one in which I believe no explorations were made. The rocks in both these areas belong to the lower portion of the Barákars, and are principally sandstones. The middle beds, which in some tracts covered by the coal measures furnish a large amount of ore for iron-smelting, do not occur. The boundaries are natural except along the line south of Khutmirkí where a fault brings the Barákars against the gneiss.

In the smaller area of Barákars, the beds occur in the form of a basin, with a moderate dip throughout. Two seams are exposed in the Bogroro on either bank, but their outcrops are very obscure, being indicated only by thin streaks of coaly shale, very much decomposed, and having nearly the whole of the carbonaceous colour washed out. The quality of the fuel which occurs in them is defined by the term "coaly shale." There is no probability of an improvement in sinking deeper, as the beds are shallow; and they cannot repay the outlay of even the cheapest method of extraction as they are too thin, neither of them appearing to be as much as 3 feet thick.

To the north of these seams and nearer the village of Khumurbad, there is a thick bed of carbonaceous shale, but with nothing worthy of the name of coal in it. The large dyke and also one of the micaceous traps cut through it.

In the larger area of Barákars, there are two small outcrops of shale dipping to the south exposed on the left bank of the Bogroro in the reach before it turns north to join the Jaintí.

About half a mile west of Chopkíarí a small seam crops out in the right bank of the Jaintí dipping south-west. The quality of the fuel it contains is somewhat better than that of the Bogroro seams.

Indications of coaly shale, but nothing that may be termed coal, occur near Kala Jherrí and Buskupí. Coal is stated to have been met with in sinking the foundations for the piers of the Railway bridge over the Jaintí. Possibly the bed seen near Kala Jherrí was struck.

Dykes.—The Talchirs are intruded into by dykes of trap, the greater number of which strike in directions between west and north. The trap belongs to the augitic and micaceous types, which ordinarily occur in our coal measures and their accompanying rocks. Of the latter type, there are only three representatives, all of which occur near Khumurbad. The dykes of this class are always thin, and affect the rocks through which they pass to a much greater extent than the augitic traps. A very distinctive feature is their being invariably decomposed and the depth to which this change has taken place.

The largest dyke in the field strikes north of Kalibad in the direction of Busjora and Khumurbad, and crosses the Jaintí river south of Turkajori. There is no evidence to show what the relations are between the micaceous and the augitic traps; but there is little doubt that all the dykes of the latter class, notwithstanding differences in direction of strike, are of one age.

The neighbourhood of the outliers has been the scene of extensive trappean action, and throughout the whole country, as far as the Rajmahal Hills, the occurrence of trap is one of the most marked geological features.

It will be clearly seen from what I have said, that there is little prospect of finding in this area a supply of coal which might be made available. And that in any summary of the coal resources of India, the field must occupy a very subordinate position.

B. *The* Sahajorí *Coal-field.*—The next outlier, for which I would propose the name of Sahajorí *Coal-field,* from the village of Sahajorí where the chief mining operations have been carried on, occupies the ground between the Adjai and the Kuchia Ghogur rivers. It possesses an area of 11 square miles of which nearly 5 are covered by the Barákars.

1. *Talchir series.*—The boundaries of the Talchirs are throughout nearly all natural. The most important fault is the one south of Nugra which affects the Barákar rocks. A small fault throws the boundary north of Burbadih, and another cuts off the Talchirs south of Kunjona. The whole of the rocks in this area are pretty well exposed, but the best sections are those of the Nugra and Beliarpúr rivers.

2. *Damuda series, Barákar group.*—The Barákars occupy but one area in this field, and the total thickness of the group may be approximately stated as 400 feet. There is no promise of *coal* in the few and imperfect sections which are visible in the rivers. In the stream south of Sahajorí, there are two outcrops of thin beds of shaly coal, that dip at angles of 8° and 10° to the south-south-east.

At the east end of the village of Sahajorí occur the coal seams into which Mr. Sandys sank a pit. Their outcrops are not exposed. At the time of my visit the workings were nearly filled with water; but I was enabled to see the end of the upper seam at the side of the inclined

shaft. The dip was gentle, and in the same direction as that of the other rocks in the neighbourhood. I saw some of the coal which had been raised from the mine at the pit's mouth, and although not equal in quality to that which Dr. Waldie analysed and that gave a percentage of 37· of ash, still it was quite capable of being employed in rough work such as burning bricks, limestone, and ordinary kunkur.

The shale accompanying the coal contains many fine specimens of *Glossopteris*.

There are no outcrops of coal between the villages of Sahajorí and Tarabad; but if experimental borings were made, it is not improbable that the continuation of the seams near Sahajorí, or perhaps new seams, would be discovered.

Immediately south of Dudhi Chuan, there is a burnt ridge that may indicate coal. It is nearly on the same line of strike as the Sahajorí seams.

A trial pit has been sunk near Tarabad, but I believe with no satisfactory result. A fault passes close to the pit which must vitiate any coal near it.

Dykes.—Besides the dyke north of Kura in the Talchirs, there is only one, and that is found in the Barákars south of Dudhi Chuan.

C. *The* Kundit Kuraiah *Coal-field.*—The third outlier, which for distinction may be termed the Kundit Kuraiah *Coal Field*, from the name of the Pergunnah in which it occurs, is about a mile and a half east of the last field, and 14 miles north of the Ranigunj field.

1. *Talchir series.*—Out of a total area of 3½ square miles, this series covers 2 miles. The conglomerate is more conspicuously exposed than in either of the other outliers, and there is a slight preponderance of sandstones over shales.

2. *Damuda series, Barákar group.*—I met with two seams, one in the Khairboní Nuddí measuring 1′ 2″ containing fair coal; and another, not so good but thicker in the Sidh river, nearly due north-east of Hairuka, dipping at 30° to the south-west.

Fault.—There appears to be only one fault, and it forms the south boundary of the field cutting off the upper beds of the Barákars.

Dykes,—Are two in number; the large one, where it passes south of Surasbad, has been utilised by the teekadar, and converted into the bund of a tank. This application of dykes to an economic purpose is to be met with in many parts of the country; and in Bundelkund I am informed by my colleague Mr. Mallet that the quartz reefs are utilised in the same way.

IV.—Economic Summary.

These fields are admirably situated with regard to railway communication.

The sandstones of the Barakârs may be employed in bridging the Jaintí just as they have been similarly employed at the Barákar river; *Kunkur* occurs over most of the Talchir area, and especially where the calcareous sandstones of the series are uncovered.

Ironstones,—do not, to the best of my belief, exist.

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

On the Geological Structure of the Country near Aden, with reference to the practicability of sinking Artesian Wells, *by* F. R. Mallet, F. G. S., *Geological Survey of India.*

The Government of India having represented to the Superintendent of the Geological Survey, the advisability of having an examination of the country between Aden and the hills to the north made by an officer of the Survey, with a view to determine the practicability or otherwise of an Artesian well for the supply of Aden with water, I received orders to stop there on my way out from England and make such investigation. In pursuance therefore of my instructions I landed on Saturday, the 19th November, and reported my arrival to General Sir Edward Russell, the Political Resident, by whom every facility was at once furnished to me for carrying out the object I had in view. On the 21st and 22nd I made some examination of Aden itself, and on the 23rd marched northward into the interior to Majhafa where the Aden troop under Captain Stevens was encamped. After having examined the country between Shaik Othman and Majhafa, I wished to enter the hills to the north; but on account of the temporarily disturbed state of the district, it was not considered safe by the Resident for me to do so, and I was obliged to content myself with a rapid march to the foot of them and return in the same day, accompanied by Lieutenant Owen of the Aden troop and an escort of Sowars and Arabs furnished by Captain Stevens. Subsequently, with Lieutenant Owen and a few of the Arab levy, I marched to the east north-east by Imad to Teran in the Abien territory, where we again

struck the hills. From thence I returned to Aden which I reached on the first of December, and sailed for Calcutta on the third.

Geological division of the country.

The country viewed with regard to water supply, as indeed in an ordinary geological point of view, naturally divides itself into three sections, 1*st*, the volcanic peninsula of Aden itself, to which may be added the hills of Little Aden on the opposite side of the harbour; 2*nd*, the plain which stretches northward to the foot of the hills, a distance of about five and thirty miles; and *thirdly*, the hill ranges to the north, which are composed of stratified rocks and run in an east and west direction. It was to the second of these, 'the country between the sea and the mountains near Aden' that the Government suggested that attention should be directed, and it was to this plain that I devoted most time, but it will be well to include the peninsula and the hills also in the enquiry.

General conditions required for Artesian wells.

Before describing the geological structure of Aden and the country to the north, it may be convenient to allude for the sake of comparison, to the general conditions of stratigraphy under which artesian borings can be made with success. The circumstances most favorable to such an undertaking are, when a thick bed of material *(b)* highly porous and permeable to water, such as sand or gravel, is intercalated between two beds

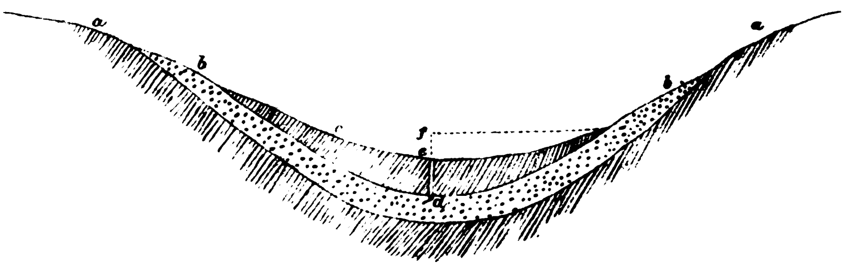

Fig. 1. Sketch section shewing general conditions favorable for artesian wells.

(a, c) of stiff clay or other impermeable material. These beds should form a more or less complete basin or synclinal, and it is necessary that some portion of the surface of the ground occupied by the bed *c* should be at a lower level than the lowest point of the outcrop of *b*. Under these circumstances, a certain proportion of the rain which falls on the outcrop of *b*, and of the water which flows across it from and beyond *a*, will soak into the porous material and permeate down to the lowest level *d*. The impermeable bed *a* prevents the water sinking lower, or keeps it up, while the bed *c* keeps it down. If then a boring be sunk at *e* down to the permeable bed, the hydrostatic pressure of the column *d b* will force the water to rise in the borehole and overflow the surface of the ground. The statical rise of the water will be equal to *e f*, *f* being the level of the lowest point of the outcrop of *b*. The actual height to which the water will rise will however be less than *ef*, as it is reduced by and depends on the amount of friction of the water and leakage through fissures, as it descends through the permeable stratum and up the borehole.

The above may be taken as the typical conditions required for an artesian well. Let us then see how far, if at all, the geological structure of the country under review approximates to them.

Aden.
Geological aspect.

Firstly, with regard to Aden itself. The peninsula, which has an extreme length from west north-west to east south-east of 5½ miles and breadth from north north-east to south south-west of about 3½, attains its highest point in Shumshum, 1,776 feet above the sea. It consists entirely of volcanic rock, and is joined to the main land on the north by a narrow neck of low-lying ground about 1,000 yards wide, which is almost sub-merged at spring tide. To the north stretches a sandy plain for over thirty miles, and thus the peninsula is a completely isolated mass of hills which must be treated *per se* with respect to water-supply. On the opposite side of the harbour is the similar but smaller volcanic mass of Little Aden.

Shumshum, the highest peak of Aden, is on the edge of the ancient crater which may be traced by eye from thence, running south-east, east and east north-east to Fisherman's Pass. In Front Bay the wall of the crater has been broken through by the sea, but again from Sher Surra point it runs along over the tunnel, past the main gate and along the northern side of the Khusaf Valley to Shumshum Peak. The crater, as it now stands, has a diameter of 1½ to nearly 2 miles, the height of the walls, except where broken through at Front Bay, varying from a few hundred to nearly 1,800 feet. The crater, however, as well as the whole volcanic mass, has been greatly altered by the action of sea and rain since the time when the volcano was active. To passing travellers it may appear strange to speak of pluvial denudation at Aden, but residents of the place are well acquainted with its force and extent. Rain seldom falls, it is true, but when it does it generally comes down in torrents. Of Aden it may be said with some degree of truth that there "it never rains but it pours." During the last fall which has occurred there (in the early part of last year), seven inches fell in a couple of hours. The water swept along in torrents, filling all the drains with stones, many of them bigger than a man's head, and doing considerable damage to the station. Such very heavy falls only occur once in ten years or so, but other smaller but still heavy ones occur at shorter intervals.

A section from west to east across Shumshum and Seerah island is somewhat like the sketch given below, which is drawn approximately to true scale, and in which I have indicated by dotted lines the portions

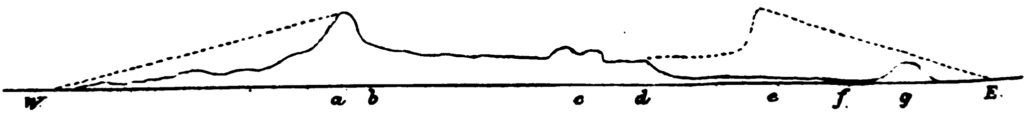

Fig. 2. Outline section across Shumshum and Seerah Island.
a. Shumshum, 1,776 feet. *b-d.* Plateau inside crater, deeply scored by ravines. *c.* Supposed central crater. *e.* Cantonments. *f.* Sea. *g.* Seerah Island.

of the original volcano which appear to have been since removed. The western flanks forming the outer slope of the volcano, and which must originally have had a much more gentle inclination, are deeply cut into by valleys and ravines, and a huge mass of matter has been denuded away. The section cuts obliquely across the flank here, so that it does not illustrate this point fully. Along the southern part of the edge there are almost vertical precipices of many hundred feet, on the outside as well as on the inside of the crater, and thus the line of hill is reduced to a mere narrow ridge; *b-d* is a plateau deeply scored by ravines, ending in one case in a fine precipice, over which the water pours in a torrent after a heavy fall of rain; *c* is a small hill (500 yards north-west of the Tawella tanks) as nearly as possible in the centre of the great crater, and containing itself a crater-like hollow, the wall of which is broken through on the east side. This hill at once suggests to one's mind the inner crater so common in volcanoes, and such I believe it to be. A large breach has been opened in the eastern side of the great crater at Front Bay: the wall has been entirely removed and also no doubt the eastern portion of the plateau *b-d*, which was originally merely the solidified floor of the crater after the last eruptions.

From the walls of the crater several long spurs are thrown off radially. Of such Marshag is one and Seerah island apparently another; a third runs northward towards the isthmus, and several smaller ones are traceable along the southern shore. The most important one, however, is that which runs westward for 2½ miles from Shumshum to Steamer-point, sending out an offshoot northward to the little pass; and which forms the backbone of all the western part of the Peninsula. It seemed to me possible that the hills from the little pass southward and eastward to Shumshum, might be the remains of another crater and not merely a denuded spur from the cantonment crater. The strata (if one may use the expression with reference to volcanic rocks) appear, as seen in a bird's eye view from Shumshum, (see Plate A.)

to dip radially from *b* and not from *c*, and in the spurs south-east of the Gold-mohur valley, which run west-south-west from Shumshum, the strata dip roughly speaking from *b* and at right angles to a radius drawn from *c*; time did not permit me to work out this point satisfactorily, but it is one worth investigation. Supposing there to be a second crater, the more imperfect state of *b*, the greater extent to which it has suffered from the wasting influence of rain and sea would *primâ facie* tend to indicate a greater age for it than for *c*, for we cannot well suppose both to have been in action at the same time, although eruptions may have taken place to some extent alternately, sometimes from one, sometimes from the other, that is to say, one may have been still active at the time of the breaking out of the second. The Twin rock and the Feringhee islets in the harbour may be remnants of the crater *b*, and Swayeea islet a spur from it, like Marshag from the cantonment crater.

The varieties of rock met with are very numerous; there are perfectly compact lavas of brown, grey, and dark green tints, sometimes containing crystals of augite and not unfrequently those of sanidin, and there are rocks exhibiting every degree of vesicularity until we arrive at lavas resembling a coarse sponge and passing into scoriæ. The vesicles again are in some specimens globular, and in others flat and drawn out. In some places the lava is quite schistose, and might if seen *per se* be easily mistaken for a metamorphic rock. Such lava is sometimes vesicular but by no means always so, at least not to the naked eye. Volcanic breccias are also met with, as near the main pass where fragments of dark green lava are imbedded in a reddish matrix. Tufas are also present but apparently to a limited extent. Some specimens of Tufa shown to me by Captain Mander, the Executive Engineer, were made up principally of fragments of pumice, from which it would appear that pumice must be amongst the volcanic products, though I am not aware of any locality in which it is found *in situ*. Obsidian is to be met with occasionally in thin seams.

Numerous dykes, varying greatly in composition and thickness, intersect the rocks, and are of interest in connection with the water question, as are also the slips or small faults occasionally met with. Secondary and accidental minerals are not numerous; chalcedony is common lining cavities in the rock, and thin seams of epidote also occur. In one place I observed a thin seam of gypsum, and close to it under an overhanging rock, a white efflorescence of common salt.

Artesian borings.

Now, with regard to the water-bearing properties of these different rocks, there are masses of compact lava, which, if free from fissures or joints, would no doubt be very nearly impervious to water; but, as far as I have observed, more or less jointing and fissuring is always present, as seen in the stone quarries above the site of the proposed new bund. Even so however a considerable degree of imperviosity might perhaps be looked for in some of these beds, and for water-bearing strata, we have the porous vesicular lavas. These, however, it must be remembered, can only be looked for in their most porous state near the top of the lava flows, as they must necessarily become more compact lower down, and therefore it is extremely improbable that a *highly* pervious lava bed of any great thickness would be found. As far as I have seen, the tufa beds are too small and local to be of any service. For an artesian boring, therefore, the most hopeful conditions to be expected are a bed of vesicular lava passing downwards into compact, but more or less jointed and fissured rock, and covered by similar compact rock of a more recent flow, and that such bed of considerable thickness and superficial extent could be found is by no means likely. The question would also be rendered more uncertain by the possible existence of dykes cutting through both porous and impervious beds, and of faults bringing one into contact with the other. Then with respect to the *lie* of such beds; in this as in other volcanoes, the strata have, taken as a whole, a quaquaversal inclination from the edge of the crater (there being however local exceptions where they have apparently been subject to disturbance

since their original formation. Such is particularly the case along the ridge between Shumshum and the main pass) exactly the reverse of the basin shaped form which beds should have, in which we seek water by artesian wells. Thus the water stored up in any porous bed must, in descending along the dip, be scattered in diverging radial lines instead of concentrated in converging ones, and any artesian boring sunk on the outer flank of the crater could only tap the water flowing along one of these lines.

Next, with reference to the catchment area. Supposing the porous lava bed between two compact ones to be found, the whole catchment area would be the outcrop *a-c* of such bed on the pre-

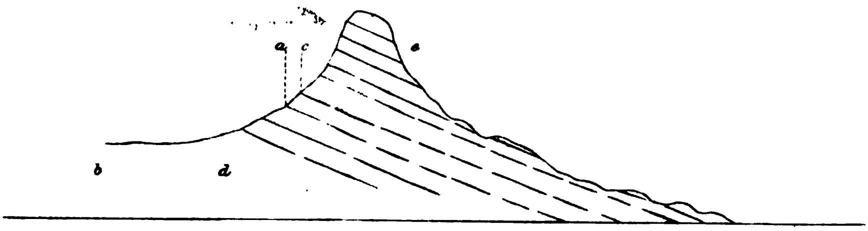

Fig. 3. Ideal section shewing escarpments of beds.

cipitous inner wall of the crater, probably not exceeding at most a few score yards in breadth, measured horizontally or in plan with reference to rainfall. The plateau *b-d* (p. 4) which would furnish a greater area, is, as far as I saw, composed chiefly of hard non-porous lavas, and they probably form a great amorphous mass, the result of cooling after the last eruptions of fluid lava in the crater itself, being therefore unstratified and not underlying the beds which form the flanks of the volcano. Further, as I have previously said, the flanks of the volcano have suffered enormously from denudation, as may be well seen in steaming along the southern shore. At the top, for several hundred feet, are precipitous cliffs, and below them the mountain side is cut into spurs and deep ravines. The denudation has apparently removed the

upper, more recent beds (*e.*, p. 8) entirely, and cut through most of the lower ones in the ravines so as to divide them into separate parts, in a water-bearing point of view. Any bed with an outcrop on the flank of the volcano, and therefore provided with a natural drainage outlet, would of course be a hopeless position for an artesian boring. From this reason alone it is only in the beds below the level of the bottom of the ravines that such could possibly be sunk, and whatever such older beds may have done in the earlier period of volcanic activity, it is very doubtful if they now outcrop in the crater. If they do not, of course there could be no catchment area to supply a porous stratum with water.

From the above considerations it will be seen that all the conditions, lithological and stratigraphical, are unfavorable in the extreme to any artesian boring, and that any attempt to sink such in the Peninsula of Aden itself would be perfectly hopeless.

Common wells.

With regard to the common wells now existing at Aden, it does not seem that much can be done for their improvement, or that a supply *considerably* larger than that at present obtained can be hoped for from them. There does not, however, seem to be any evidence that the present yield is less than that of former years. Captain R. Foster in a paper published in May 1839, in the proceedings of the Bombay Geographical Society, writes: "The supply of water at Aden is one of the most curious features of the place. It is found at present in the valley of Aden town only, and close up under the cliffs, and at the opening of the fissures from the steppe above; in the valley there may be upwards of one hundred wells, chiefly dilapidated and choked up, but some piercing to a great depth, and yielding abundant and excellent water."

"The whole of the inhabitants, troops and all were supplied during my residence there from only four of these wells, and notwith-

standing this heavy draw on their contents, they were reduced but a very few inches in a space of seven weeks."

As the supply of water is now deficient, it would appear at first sight that it must have diminished since 1839, but it would seem that the increased demand for water since then is fully adequate to explain the apparent falling off. Captain R. L. Playfair in his History of Arabia Felix* gives the following statement of the population of the town at different times:—

Population at conquest by British,	16th January 1839	...	500
Ditto	September 1839	...	2,885
Ditto	March 1840	...	4,600
Ditto	1st January 1856	...	20,738
Ditto	„ 1859	...	25,000

As Captain Foster's paper was published in May 1839, it must have been written immediately after the taking of Aden when the population wss only 500. The subsequent English garrison must be added to this number, but in September of that year it was still only 2,885: and as it is now, as I was informed by Sir Edward Russell, probably not less than 30,000, the population has increased since the date of Captain Foster's paper fully fifteen fold, and the demand for water of course in a somewhat similar ratio.

The area in the crater in which wells yielding drinkable water can be sunk with success is very limited. The rocky plateau previously described (*b-d*, p. 4) occupies two-thirds of the crater, and here, besides the difficulty of carriage down to the cantonments, water could not be expected except at a greater depth than in the low ground at the foot of it. In the low ground again in which the cantonments are built, the wells as they approach the sea become brackish and undrinkable.

* Selections from the Records of the Bombay Government, No. XLIX, New Series.

Captain Playfair writes that "water of good quality, but in limited quantities is found at the head ot the valleys within the crater and to the west of the town. As the wells approach the sea, they become more and more brackish, and those within the town are unfit for any purpose save ablution. The wells within the town have an unlimited supply at from 30 to 40 feet, but the water contains as much as 10 parts of saline matter in 2,000 and is therefore unfit for drinking."

Thus the available area for good water (the very best well water in Aden still having a perceptibly brackish taste) is limited to the low ground immediately at the foot of the plateau, the sites naturally selected as yielding most water, being where the watercourses from the plateau debouch into the plain. Of such nullas there are three: that which supplies the Tawella tanks; the one which debouches above the Residency, the water of which it is proposed to collect by bunding, and that of the Khusaf valley, up which the wells extend for a considerable distance. Altogether according to Captain Playfair "these (the wells) are in number about one hundred and fifty, of which probably fifty are potable, and yield an aggregate quantity of about fifteen thousand gallons per diem. They are sunk in the solid rock to a depth of one hundred and twenty to one hundred and eighty-five feet, and in the best one the water stands at a depth of seventy feet below the sea level. The Banian well, the best in Aden, is 185 feet deep, the bottom is 70 feet below the level of the sea, and before being drawn it contains about 4,000 gallons. The temperature of the water is 102° Fahr., the specific gravity ·999, and it contains 1·16 parts of saline matter in every 2,000." This Banian well, as I was informed by Captain Prideaux, yields 3,000 gallons a day after the longest drought.

In endeavouring to increase the supply from the available area, one of two courses would have to be adopted: either the number of wells might be increased, or some of the existing ones might be enlarged and sunk deeper.

In the former case, there can be no doubt that the new wells, situated as they must be, in ground already thickly dotted over with old ones, would derive their supply chiefly at the expense of the latter, and that the total yield would not be largely increased. The whole drainage area to supply them is very limited, less than two square miles, and the average annual rain-fall very small also, and it seems that the limited quantity of water which exists stored up in the rocks, is already economized nearly as far as it can be.

The second expedient, to deepen the wells, would not result in any useful augmentation of the supply, for it appears from information kindly obtained for me by Captain Mander, that the wells if sunk deeper than at present, become more brackish. The bottoms of them are now below sea level, and they have all of them a more or less brackish taste, although it is very slight in the best. Even into them it would seem that there is some infiltration from the sea, and apparently as they are sunk deeper and the hydrostatic pressure from the sea becomes greater, the amount of infiltration increases. Such being the case, a deepening of the wells would no doubt increase the yield more or less, but the quality of the water would be deteriorated.

I think there can be no doubt that the wells derive their brackish taste mainly from the sea, as is sufficiently shown by the undrinkable quality of the wells in the town, and the increasing purity of the water as they recede from the shore, as well as by the increased brackishness if they be sunk deeper. A certain contingent of saline matter may, however, be furnished by the rocks themselves. Chloride of sodium is a very common mineral in volcanic rocks, and its presence in those of Aden is shown by an efflorescence of it which I observed 200 or 250 feet above sea level, on the hillside above Toowye. Careful analyses of the waters of the sea and of the different wells, might furnish data to determine the relative proportions in which the well water is affected by the sea and by the rocks.

It appears that in all the wells there is infiltration of both fresh and salt water,* the quality depending of course (excluding the influence of the rocks) on the relative proportions of the two. After long droughts when the infiltration of fresh water is diminished, the wells become more brackish, the infiltration from the sea remaining the same, or increasing from the lowering of the water-level in the wells and consequent increased pressure from the sea.

A certain amount of water could undoubtedly be obtained from the Gold-mohur and adjacent valleys on the south-west flanks of the volcano, which, *if good,* might be made available, as far as it went, for the supply of Steamer Point, although the digging of fresh wells in the peninsula could not be recommended when there is a prospect of any scheme being carried out for the complete supply of the station with water. It appears, however, from Captain Foster's paper that wells have already been sunk in this locality, and that the water was of an unpalatable kind. He says,—" Vestiges of former wells still exist in western bay, and from the similarity of position and character of the bays to the west and south-west, I have no doubt that water may be found in them also; in one or two wells lately opened the water was found bitter, the flavor was attributed by the Natives to the roots of some bush, but might not that be owing to the presence of certain minerals, with great varieties of which the whole peninsula abounds." The bitterness of the water is very possibly to be attributed to saline minerals in the rock, but I cannot endorse Captain Foster's statement that the peninsula 'abounds in great varieties' of such.

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* I was informed by Captain Mander that the Somaulis dig shallow wells near the shore in certain places which are dry at low tide, but yield a little fresh water at high tide, the explanation he gives being that the fresh water which trickles away at low tide, is bunded back at high tide by the salt water.

Little Aden.

As the time at my disposal was so short, I did not think it advisable to curtail my visit to the interior, in order to examine Little Aden, on the other side of the harbour, in detail. The hills there, however, being also volcanic, and similar to those of Aden itself,* it is, I think, certain that any artesian boring there would be equally hopeless. A small quantity of water could probably be obtained from common wells similar to those of Aden, but not in sufficient amount to be worth the expense of transport either across the harbour in water-boats, or round it by an aqueduct.

Plain to the north of Aden.

Physical aspect.

A sandy plain (see Plate B.) stretches northward from Aden to the foot of the hills, a distanee of five and thirty miles or thereabouts. As I had only one fixed point (Aden itself) from which to take bearings with the prismatic compass, I was unable to fix the position of the hills with accuracy, and the distance therefore is open to some little uncertainty. The isthmus connecting Aden with the main land is scarcely above high water mark, and thence northwards one passes over a sandy plain, which is almost a dead level until, within perhaps half a mile of Shaik Othman, the country rises a few feet. At this village there is some alluvial soil. From this northward to Majhafa the country rises very slightly. It is a sandy, slightly gravelly plain, with fine blown sand in places, and covered thinly in parts with scrub jungle; the jungle was in former years much thicker, but it has been constantly reduced by the demand for firewood at Aden. To the west of this line, from Dharab northwards for many miles, there is a large tract of rich and well cultivated soil in the midst of which stands Hota or Lahej, the residence of the Sultan, who rules the Abdali tribes of the surrounding country. This

* Since my return to Calcutta I find that Dr. Carter in his Memoir on the geology of the south-east coast of Arabia, states that it is *said* that these hills are composed partly of granite, but gives no authority for the statement. Even if this be the fact, the chances for a successful boring would not be greatly increased.

oasis is well watered by a river which debouches from the hills to the west of Jibal Manif, and after flowing past Zaida, divides into two branches north of Lahej. One (Wadi el Kebir) after passing Mahilla, Wahud and other villages, reaches the harbour of Aden at Huswah, but it is only during heavy floods that any water ever reaches the sea. It is all accounted for higher up the stream by its use for irrigation, soaking into the sand and evaporation. The other branch of the river runs by Majhafa, Froosh and past Imad. It is from the water of this river that the Sultan derives a large portion of his revenue, it being sold by him to the villagers at fixed rates, and the luxuriance of the crops raised with its aid on the fine alluvial soil of the district, is very striking in the midst of such a sandy desert. To the west of the oasis the country is a sandy desert for five and twenty miles, until one reaches the equally well cultivated Abien tract watered by the Bunna and Hassan rivers flowing southward from the hills.

From Majhafa northwards the cultivation extends two miles or so. After that one passes over a sandy plain (gravelly in places), which rises a little towards the north. At 10 or 12 miles from Majhafa one enters on a belt of country extending from thence to the foot of the hills, in which one passes over ridge after ridge of blown sand, each ridge rising higher than the preceding one, so that the foot of the hills is, as measured by aneroid, 800 feet above the plain at Majhafa. This difference is greater where I marched across them than to the west where it is not more than 600 feet. The billow like ridges run west north-west and east south-east, and are thinly covered in places with coarse grass.*

Geological structure.

The only obtainable sections illustrating the geological structure of this plain are in the wells. Most of them are lined with stonework, but of those which are not so, I

* One of the Arabs picked up here some small fragments of an ostrich egg browned by the weather, which were interesting as being probably evidence of the former existence of these birds in this part of Arabia where they are now extinct.

obtained as many measurements as possible. At Shaik Othman the section in one well was as follows:—

No. 1.

	Ft.	In.
Surface soil (slightly clayey or silty sand, passing downward into sand.)	6	0
Sand	3	0
Pebbly layer	0	1
Sand	4	8
Pebbly layer	0	3
Sand	3	0
	17	0

	Ft.	In.
Depth to water	17	0
„ of do.	1	0
	18	0

Water rather brackish.

WELL No. 2.

	Ft.	In.
Surface soil (brown alluvial silt)	2	6
Sand with one or two thin pebbly layers	12	3
Pebbly layer	1	3
	16	0

	Ft.	In.
Depth to water	16	0
„ of water	1	6
	17	6

Water same in taste as in No. 1.

A third well was 17 feet to the surface of water. The slightly lesser depth of No. 2 is evidently due to inequality of the surface, and not to difference in the water line, which in such highly permeable strata of loose sand is no doubt the same in all the wells, except in so far as it may be temporarily altered by drawing. The bottom of No. 1 is of loose sand and of No. 2 apparently of pebbly sand, there being no more impermeable stratum at the bottom of the wells. The wells here become brackish and undrinkable if sunk a few feet deeper, undoubtedly from the infiltration

of sea water. The pebbles in the pebbly layers are well rounded, the largest being about two inches in diameter, and are all of volcanic and metamorphic rock. The sand is quite loose and incoherent, and the cultivable soil consists of a thin covering of silty alluvium over the sand—

	Ft.	In.
In the well at Imad the depth to the water is	30	0
Depth of water	8	0
	38	0

The ground here however is uneven, so that the depth of this well from surface does not give a fair indication of the water level. The water is brackish and warm. The well is lined so that no section is obtainable, but the surface soil is very sandy silt. At Bir Muktoe 17 miles or thereabouts to the eastward there is a—

	Ft.	In.
Shallow 'kutcha' well in which the water is from the surface	6	0
Depth of water	0	9
	6	9

It is very brackish, but is said to become sweet after being largely drawn on. In a shallower well close by the section was—

	Ft.	In.
Surface soil (clayey silt more or less sandy in parts) ...	3	0
Sand	1	0
	4 .	0

In a well at Mahilla, 12 miles north-west of Shaik Othman, the following section is visible :—

	Ft.	In.
Silty soil becoming more sandy below	20	0
Sand	4	0
Conglomerate, of rounded pebbles up to 6″ and 8″ in diameter imbedded in loose sand	27	0
	51	0

	Ft.	In
Depth to water	51	0
„ of water	2	6
	53	6

The pebbles in the conglomerate are nearly all volcanic, there being however a few of metamorphic rock.

	Ft.	In.
In another well the depth to the water was	53	0
Depth of water	2	0
	55	0

The water here is perfectly sweet without the least trace of brackishness. In common with, I believe, all the wells of the Lahej neighbourhood it comes from the well quite warm. I had no thermometer with me and could not measure the exact temperature, but it appeared to be certainly above the mean temperature of the place. The Banian well in Aden is according to Captain Playfair 102° F.—

	Ft.	In.
In a well at Majhafa the depth to water is	54	0
Depth of water	8	0
	62	0

The lower part of this well is lined. The 27 feet at the top, unlined, is of silty soil, more or less sandy, very sandy in places. The lowest three or four feet is moist at one side from the slow infiltration of water.

In comparing the sections at Shaik Othman near the coast and at Mahilla further inland and further up the course of the river, it will be seen that at the latter there is a thick bed of conglomerate, in which the well-rounded water-worn pebbles range up to six and eight inches in diameter, while at Shaik Othman the largest do not exceed two inches, thus giving us a very good clue as to the direction from which the pebbles have come. Captain Foster mentions that the low water line at Aden has receded within the recollection of the present generation, and Captain Playfair in his history of Arabia Felix states that "the latter (the Tehamás or low country*) varies in breadth from thirty to eighty miles. The soil is poor and arid, covered in many places

* Of which the plain north of Aden is a portion.

with marine shells and coral, and bears unmistakably the appearance of having been a recent recovery from the sea; that the sea has greatly receded even within the limit of history, is proved by the position of the ancient seaport of Mooza, formerly one of the principal emporia of the trade of Yemen, but now situated twenty-three miles inland, north of the modern city of Mokká. In like manner, Ghalifica, the port of Zebeed, Okelis and many others along the coast of the Red Sea, have filled up and been deserted." I do not know whether there be any evidence or not to prove a gradual elevation of the coast at Aden, which would in itself, of course, cause the shoreline to recede from the hills, and enlarge the area of the plain. There can, however, I think, be no doubt that the materials of which the plain is formed, have been brought down from the interior by the rivers in the ordinary manner of delta formation, and that they are not the result of degradation of the hills by the sea itself when the land stood at a lower level, although the sea may have had some effect in sorting them perhaps. The southern flanks of the hills, where I had an opportunity of examining them, are of stratified rocks, and I believe that they are formed of such all along here. It is on these, it would certainly appear that the action of the sea would expend itself, but the pebbles in the conglomerate beds are all volcanic and metamorphic. It might be expected that as the rivers flow last through stratified rocks, the pebbles brought down by them would consist chiefly of such, but such is not the case. Thus in the Hassan River two or three miles below Ulkhour, where it leaves the hills, pebbles and boulders from the interior, of metamorphic and volcanic rocks, up to a foot in diameter are abundant, but those of limestone, &c., are rare and small sized.

A sketch section from Aden to Lahej and thence northwards to the hills is given on Plate B. I do not know what the exact elevation of Lahej above the sea may be, but it is very small and no doubt exaggerated in the section.

Wherever I obtained well sections in the plain between Aden and the foot of the sand hills, there was more or less silty alluvial soil at the surface, amounting in thickness to a few feet at Shaik Othman, but at Majhafa and thereabouts, to 20 or 30. Between the cultivated lands are large patches of sand, and I am not certain whether the alluvial soil is continuous over the whole plain, being covered over and concealed in places by blown sand, or whether it is absent in some localities: but I am inclined to believe that it is continuous.

Beneath the surface soil is sand passing downwards into gravel, the whole being stratified horizontally or more probably having a gentle dip towards the sea corresponding with that of the plain. To the north are the blown sand hills, which rise 600 or 800 feet from the plain to the foot of the hills, and which have been produced by the latter acting as a sort of 'dam' to the current of sand carried along by the south-west monsoon. There can be no doubt that the sand here is several hundred feet deep.

Artesian wells.

Although there is abundance of excellent water stored up in the stratum of sand and gravel beneath the plain, it is self evident that such water cannot be obtained by means of artesian wells, for the very simple reason that the wells from Shaik Othman to Lahej are sunk down to this water-bearing stratum, and that the water does not rise above it. Even supposing the hydrostatic conditions to be otherwise favourable, there is no impervious stratum above the gravel bed. The surface alluvium is always more or less sandy and could not keep the water down were it inclined to rise; that it does not do so is clear from the fact of all the existing wells piercing through it.

The only chance therefore for an artesian boring lies in the possibility of an impervious stratum existing beneath the gravel bed, and under that again a second water-bearing stratum. I have no means of forming an opinion as to how deep the gravel bed goes, but from the increasing coarseness of the materials in descending, and the

mode of formation of the plain from detrital matter brought down to the sea by rivers (mostly during floods), there is little reason to expect any transition lower down, to plastic clay or other impermeable material. It seems to me by no means improbable that the gravel extends down to the solid rock beneath, which would perhaps be found at no very great depth. Even if an impervious stratum should exist beneath the gravel, it would be necessary that the lower porous stratum should outcrop to the north, at a level sufficiently above that of the surface of the ground at the proposed well, to provide sufficent hydrodynamic pressure to overcome the friction of the water through the gravel. The very gentle inclination of the plain does not favour such an arrangement, and even were it found to exist,—unless by thinning out of the water-bearing stratum between two impervious ones or other means, the water were prevented from flowing on direct through it to the sea,—no sufficient pressure could be expected, to force it up the borehole or well.

The sandhills to the north, consisting, as they undoubtedly do, of loose sand for several hundred feet in depth, are of course quite out of the question in respect to artesian borings.

It would be useless to speculate on the solid rock beneath the plain without accurately knowing what it is, whether volcanic, metamorphic or stratified, or anything of its stratigraphical relations; but from all I know of the rocks of the country where they are visible, I see no reason whatever to *expect* a successful result in sinking down to them beneath the plain.

Common wells.

The stratum of sand and gravel beneath the plain contains, as I have said before, an abundant supply of water stored up in it, although such cannot be made available by *artesian* wells. The river which leaves the hills to the west of Jibal Manif, has a bed at Zaida, as observed by Captain Mander, of 300 yards in breadth. Where I crossed the western branch (Wadi el Kebir) below Lahej on the 27th November, the stream was about

6 inches deep and 15 or 20 feet broad, with a rapid flow of water. As far as, and even beyond Lahej, the river is never dry throughout the year, but it is only after the heaviest floods that a drop reaches the sea. The water which leaves the hills therefore is all disposed of in passing over the plain, by evaporation,—which as the water is so largely spread over the fields for irrigation purposes, no doubt accounts for a considerable fraction of it,—by absorption by vegetation, and lastly and I believe chiefly, by soaking into the ground. Flowing as the river does over sand and sandy soil, for some 20 miles as the crow flies, from its debouchure out of the hills to where it becomes dried up, the loss by absorption into the ground cannot but be enormous, and we accordingly find the gravel bed south of Lahej saturated with water at about 50 feet below the surface. No doubt there is a slow underground current towards the sea, particularly beneath the bed of the river. At Huswah, close to the shore of Aden Harbour, I was informed that while one well dug some distance from the river course yields brackish water, another in the bed of the stream affords water which is pure and good, no doubt owing to an underground flow.

Around Lahej a large quantity of water is obtained for irrigation by means of common wells, and the yield is plentiful although the depth to which they are sunk below the water line is very small. The deepest I measured contained eight feet of water, and another at Mahilla, only two, the water in this however having been lowered by drawing. The water in this, as in all the wells of the neighbourhood which I examined, was perfectly sweet and good. It was being drawn out for irrigation as fast as the cattle could raise it. The bullocks work four hours a day, two in the morning and two in the evening, but the villagers said that if the water were required, they might work constantly without draining the well, and such I have no doubt is the case, for as the water-bearing stratum consists of rounded pebbles imbedded in loose sand, the water is free to percolate through it with the greatest

rapidity. The natives further say that (unlike Shaik Othman) increasing the depth of the wells produces no brackishness, and here again I believe they are right. I do not know what the elevation of Lahej above the sea may be, but even if the wells were sunk much below sea level, the distance from the sea is probably too great to allow of any infiltration from it, or even if such could take place, it would be quite inappreciable in comparison to the influx of fresh water. According to the natives, the wells yield an equal quantity of water throughout the year. The water-bearing stratum must no doubt be kept saturated, as long as the river contains running water to soak down to it, that is to say all the year round since the river is perennial.

If then the present wells, sunk a few feet below the water-level, yield abundant water to supply the demand upon them for irrigation, what would be the yield of one or more wells sunk 50 or 100 feet below that line? There is of course the possibility that the solid rock, or less porous strata, might be met with before such depth should be reached, but assuming that the gravel bed extends down to a sufficient depth, there cannot be the least doubt, taking into account its highly pervious nature, which would allow the water to flow rapidly in from a very large circumference, and that the river is at hand to supply the porous stratum with water as fast as it is drawn off, that a well sunk to a considerable depth below the water-level would yield a very large quantity of excellent water, and that this is *one* means by which Aden could be fully supplied. Of course it would be necessary to raise the water to the surface by some description of pumping apparatus, and power would have to be provided for such purpose. It is worthy of consideration whether such could not be found in the wind. From information supplied to me by the Harbour Master at Aden, it appears that the prevalent winds there are south to south-west during the south-west monsoon, from the beginning of June till the end of August. During September and beginning of October, little or no breeze and variable

winds. Easterly winds during the north-east monsoon from the middle of October till the end of March. During April and May variable winds and calms. It seems that there are usually not more than two months of calm in the year, there being generally more or less breeze for the remaining ten. Other power would have to be provided for the periods of calm, and for such other times as the wind might not be sufficiently powerful to raise a full supply of water. The following table shows the engine power (working 18 hours a day) required to raise 600,000 gallons per diem, which taking the population of Aden at 30,000 would allow 20 gallons per day per head:—

Height raised in feet.	Depth below water-level at Mahilla.*	Horse power.
60	9	10·1
70	19	11·8
80	29	13·5
90	39	15·2
100	49	16·9

In fixing upon the site on which to sink a well, the nearest point to Aden should be chosen at which it could be sunk sufficiently deep to yield the required supply, without producing any trace of brackishness in the water obtained. The nearness to Aden would be important not only on account of the shorter length of aqueduct or piping required, but of the lesser depth of the water-level from the surface, and consequently the reduced pumping expenses. I believe that at Mahilla, about 19 miles from the cantonments, the two conditions of sufficient supply and complete freedom from brackishness can be obtained, and probably nearer, but *how much* nearer, I am not prepared to say. This point ought, however, to be investigated by means of trial borings, before entering on any permanent works. Such borings ought to be

* In one well which I measured at Mahilla, the water stood at 53 feet from the surface, but it was being drawn on at the time for irrigation. In another, out of work, the water-level was 51 feet from the surface.

made near the river course, in the vicinity of which the supply of water is probably greatest, on account of the underground flow of the stream.

One disadvantage of such deep wells would be, that if through pumping, the level of the water in them stood considerably lower than the normal water-level of the locality, the existing village wells of the neighbourhood would undoubtedly be laid dry.

In suggesting one or more such wells, I would not be understood as *advocating* them, as superior to the schemes already proposed for the supply of Aden. I merely point out that the town *can* be supplied in this manner, and that it is a means worthy of consideration, leaving the relative merits of the different proposals to future and more detailed investigation.

Hills north of Aden.

From Majhafa, I marched nearly due north to the foot of the hills, but on account of the disturbed state of the country, I was unable to enter them. The summits of the main range (Jibal Shiap) which are marked on Dr. Carter's sketch map of the south-east coast of Arabia as 6,000 feet high, are fully 10 miles beyond the most southern outliers, the intervening space being occupied by detached hills, and wastes of blown sand. The section in the outermost range of hills is as shewn in the sketch given on Plate B. The limestone is not less than 600 or 700 feet thick, and may be much more, as time did not permit me to visit the beds *a*. It is of a light grey color,* in beds of moderate thickness, an occasional band of flaggy

* The following are two analyses of this limestone by Mr. A. Tween, from which it will be seen that the rock is nearly pure carbonate of lime. For hydraulic purposes, lime made from it would require mixture with some material, like the pumiceous tufa of Aden, which is now used for the purpose mixed with burned coral. No. 1 is a light grey rock; No. 2 one of a darker shade.

	No. 1.		No. 2.
Loss on ignition	·8	...	2·0
Insoluble	·4	...	2·95
Residue—Carbonate of lime, with traces only of magnesia, alumina, iron and phosphoric acid	98·8	...	95·05
	100	...	100

No. 2 contains most magnesia and iron, but less than 0·3 per cent. of either.

sandstone being met with near the junction with *c*, there being a passage from *b* into *c* showing that both belong to the same formation. Similar bands also occur in the lowest portion examined, so that the strata at *a* are not improbably sandstone. The limestone abounds in fossils numerically, although the number of species does not seem to be very large. Dr. Stoliczka, who has examined the specimens I obtained, observes respecting them that the "limestone is full of sections of a long turreted *Nerinea*, a species of *Cryptoplocus*, of a Pelecypod, probably a *Corbis*, and large numbers of a *Spongites*, generally dichotomous. The limestone is evidently of mesozoic age, and the few fossils appear to resemble most upper jurassic forms, though the same genera also occur in lower cretaceous beds." The sandstone is white, grey, or reddish. It is a coarse rock, pebbly in places, the pebbles being of red and white quartz. From *c* to *e* is fully 2,000 feet. The dip of the limestone and sandstone is south-west at about 40°, which is more or less the dip of the beds in all the neighbouring hills. In one, some distance to the north-west, however, the dip is reversed to north-east at 40°. Lines of stratification are visible in the hills to the north and north-west as far as one can see.

At Ulkhour, 25 miles to the eastward, the outermost hills are of grey limestone, lithologically quite similar to that north of Majhafa, but I observed no fossils in it. In one place it contains a thin band of quartzite, and I also remarked a dyke of earthy trap, cutting nearly vertically through the bedding. The limestone is several hundred feet thick, with an easterly irregular dip of about 30°; the hills to the west are also of stratified rock, and I believe the latter is continuous to where I examined them north of Majhafa.

In the Hassan river where I crossed it two or three miles below Ulkhour, pebbles, and even boulders of a foot diameter, of metamorphic and volcanic rocks are abundant. The former include gneiss, in which the foliation is distinctly seen, composed of red felspar, quartz, and dark green mica, and a somewhat similar rock without foliation which may

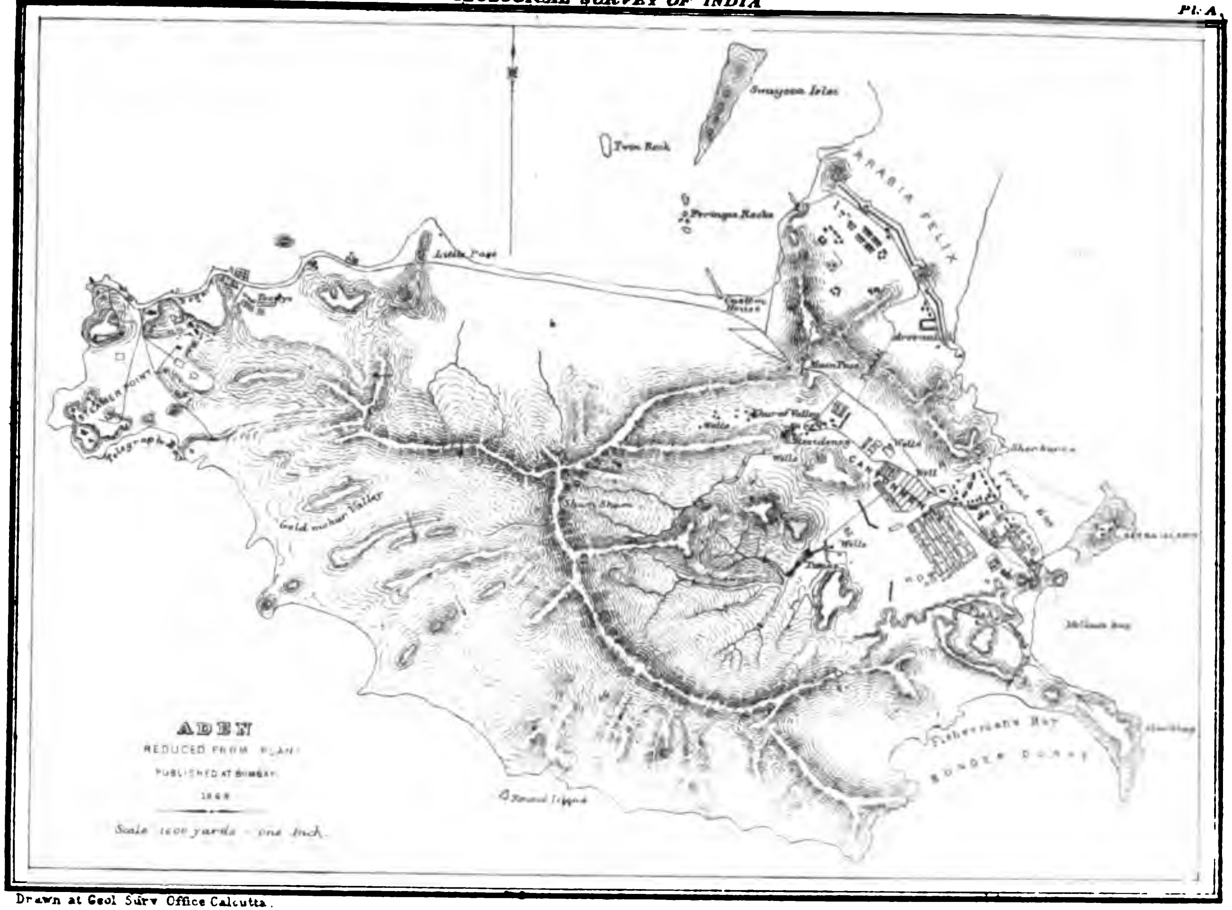
possibly be granite; also hornblende rock with lines of foliation, granular quartzite or quartzitic sandstone and white translucent vein (?) quartz. Amongst the volcanic pebbles are those of basalt and of very vesicular or scoriacous lava. The metamorphic pebbles are far more plentiful than the volcanic, from which it might be inferred that the latter come from a greater distance. By the same rule, however, the limestone rocks would be the furthest off of all, as pebbles of such are the rarest, while in reality they are the last beds through which the river flows. This is worthy of note, for in the Wadi el Kebir, below Lahej, metamorphic and volcanic pebbles are common, whilst there are none of limestone or sandstone; but this fact does not prove that the southern flanks of the hills, where the river debouches from them west of Jibal Manif, are not of stratified rock.

The pebbles in the Wadi el Kebir include foliated gneiss with white felspar, quartz and black mica, a white non-foliated felspathic rock, possibly granite, and different varieties of lava.

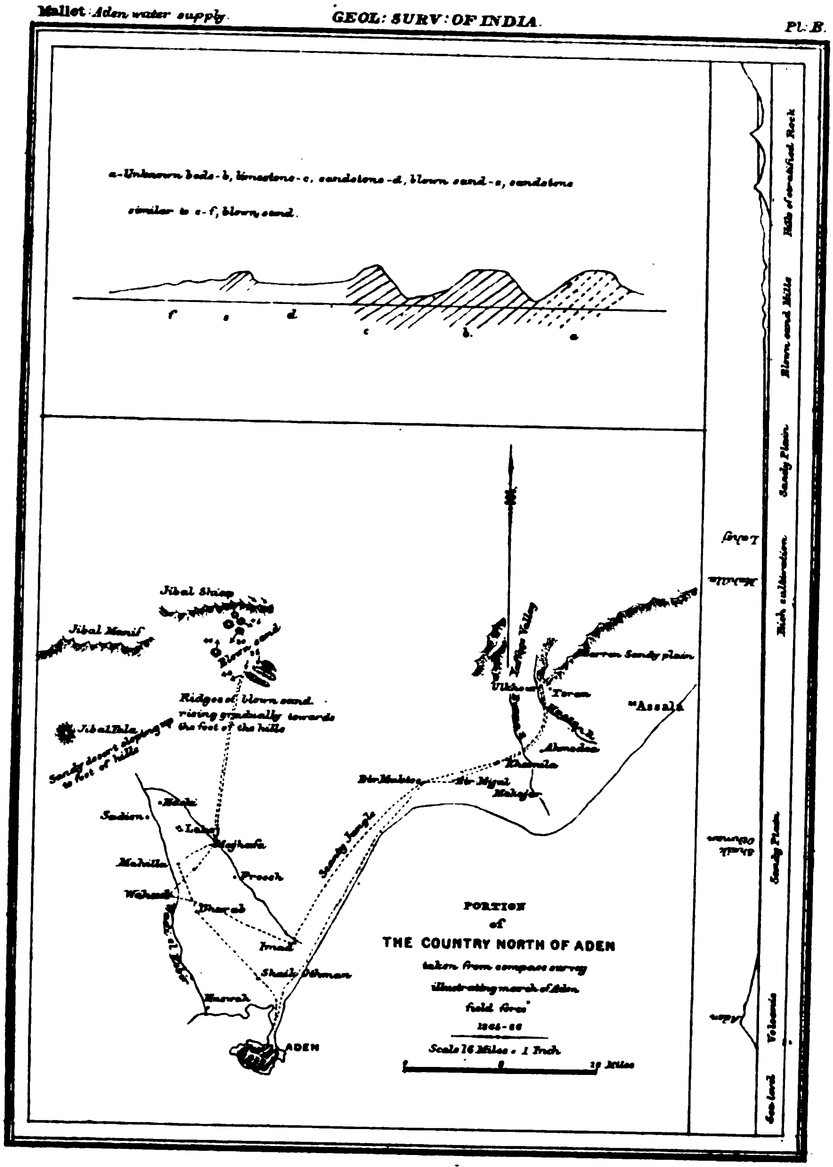
It appears then that the Jibal Shiap range of mountains to the north and north-east of Aden, are composed of metamorphic and volcanic rocks, with stratified rocks of mesozoic age on the southern flanks, the latter having a southerly dip and very probably overlying the metamorphic.

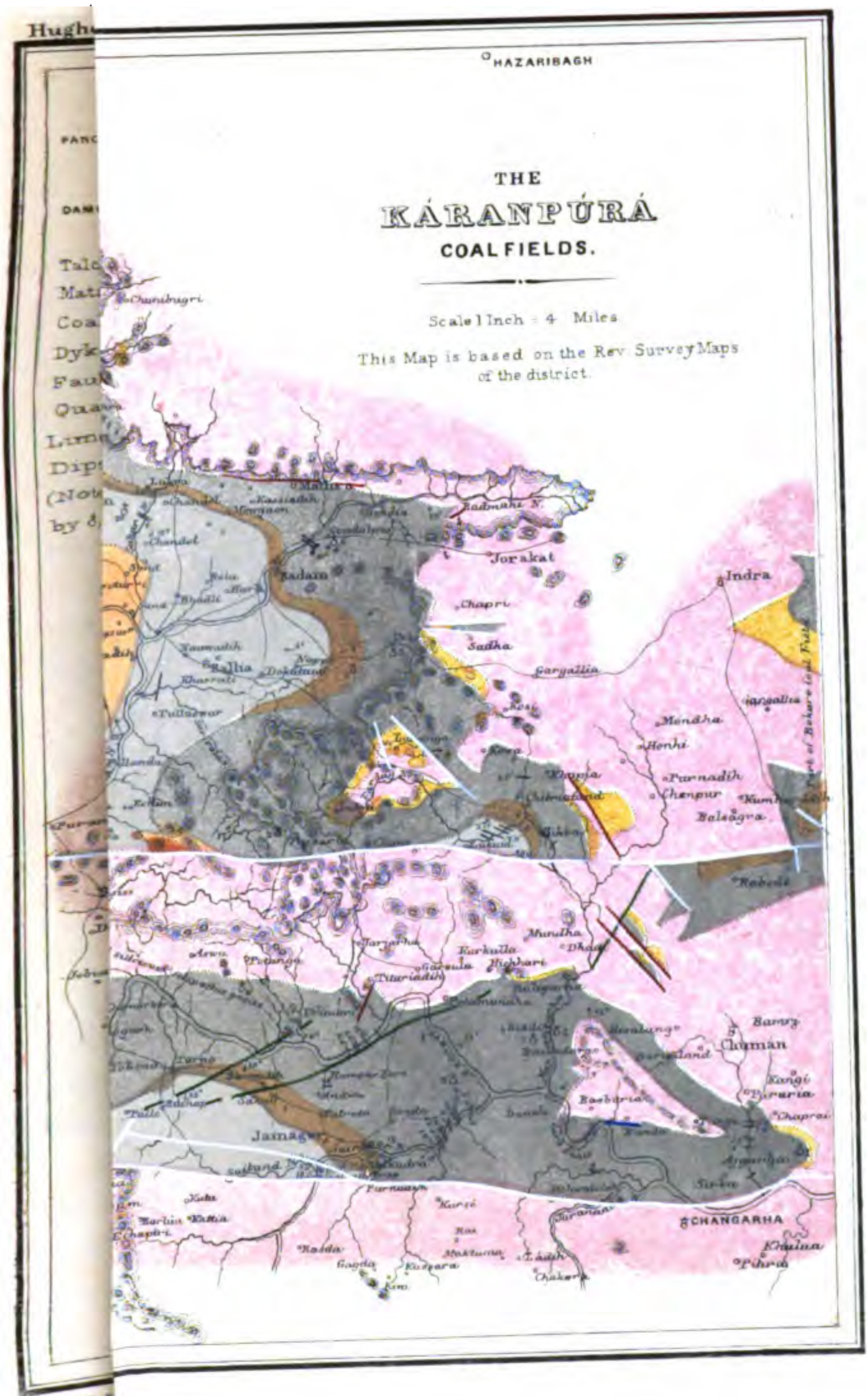
Where I visited the most southerly outliers of the hills, the conditions necessary for artesian borings are certainly not present; whether they be so further north, in the interior of the main range, I cannot pretend to say; but the point is not one of much practical importance, for the expense, the engineering difficulties, and the uncertainty, of bringing water 40 or 50 miles, from an elevation of more than 1,000 feet and through a desert constantly liable to the incursion of hostile tribes, quite suffice to put the Jibal Shiap mountains out of the question in any scheme for the water-supply of Aden.

In concluding this report, I would take the opportunity of expressing my thanks to General Sir Edward Russell and the Assistant Resident, Captain Prideaux, as well as to the other officers of the station with whom my duties brought me in contact, for the facilities afforded me in carrying out my investigations and for the personal kindness I experienced during my stay at Aden.



Drawn at Geol Surv Office Calcutta.


a-Unknown beds-b, limestone-c, sandstone-d, blown sand-e, sandstone similar to c-f, blown sand.
f
e
d
c
b
a
Ridges of blown sand rising gradually towards the foot of the hills
Sandy desert sloping up to foot of hills
Lahej
Majhafa
Imad
Shaikh Othman
ADEN
Toran
Assala
Barren Sandy plain
Sandy Jungle
PORTION
of
THE COUNTRY NORTH OF ADEN
taken from compass survey
illustrating march of Aden
field force
Scale 16 Miles = 1 Inch
Miles
Sea level
Volcanic
Sandy Plain
Rich cultivation
Sandy Plain
Blown sand Hills
Hills of stratified Rock



HAZARIBAGH
THE
KÁRANPÚRÁ
COALFIELDS.
Scale 1 Inch = 4 Miles
This Map is based on the Rev. Survey Maps
of the district.
Chumbugri
Jorakat
Chapri
Sadha
Garyallia
Indra
Mendha
Honhi
Purnadih
Chenpur
Balsagra
Rebede
Muntha
Karkulla
Jamager
Chuman
Kangi
Chaprai
CHANGARHA
Pihra
Hughes
Drawn

MEMOIRS

OF THE

GEOLOGICAL SURVEY OF INDIA.

The KÁRANPÚRÁ COAL-FIELDS, *by* THEO. W. H. HUGHES, F. G. S., *Assoc., Roy. School of Mines, Geological Survey of India.*

The description in this memoir of tho Káranpúrá coal-fields, brings to an end the history of the mineral wealth of the Damúdá valley, in connection with its coal and iron-bearing deposits, which was commenced by the issue of the report on the Rániganj field, and systematically continued in those of the Jherriá, the Bokáro, and the Rámgarh fields.

The total area of all the Damúdá coal-basins is about 2,000 square miles, estimated as follows:—

1.	Rániganj	1,000	square miles.
2.	Káranpúrá	472	„ „
3.	Bokáro	220	„ „
4.	Jherriá	200	„ „
5.	South Káranpúrá	72	„ „
6.	Rámgarh	40	„ „

The size of the Rániganj field is stated approximately. Its known area is 600 square miles, but there is every reason to suppose that it extends for many miles eastward beyond the furthest known point in that direction. The areas of the other coal-basins are accurately given, as they differ from the Rániganj field in having their boundaries definitely terminated by the appearance of the crystalline series, which, in the Damúdá valley, forms the floor upon which the coal measures and their associated rocks rest.

The Káranpúrá fields, although now distinct and forming two separate basins, were originally one continuous tract. The denuding action of the Damúdá river has exposed an intervening strip of gneiss, that cuts the one off completely from the other. To each, therefore, it has been necessary to give a separate title. The larger, I have called the Káranpúrá, and the smaller the south Káranpúrá field.

In giving this title, I have departed from the usual custom of retaining the name applied by the first observer.

But Mr. Williams, the only observer that I am aware of, who recorded any observations regarding these fields, adopted the local name of a river,—the Hohárú—so little known beyond a radius of two miles from the village where it was in use, that I have felt no hesitation in setting it aside and adopting as the title of these fields the well-known name of the parganáh in which they are for the most part included.

It would be possible to notice both the Káranpúrá and the south Káranpúrá under one heading; but for the convenience of stratigraphical description, I have thought it advisable to treat them separately. The Káranpúrá being of greater extent than the other, will occupy the first part of this memoir.

THE KÁRANPÚRÁ COAL-FIELD.

In the literature, other than that of the Geological Survey, relating to the Damúdá valley, attention has never been drawn to the Káranpúrá field as a coal or iron-producing district except by Mr. Williams. In 1848, he examined a small portion of the eastern extension of the coal-basin in the neighbourhood of Chano and Badam, and gave it the title of the Hohárú (Hobaroo) coal-field. This name, as I before remarked, has not been retained. There is nothing, purely geological, of any interest to notice in Mr. Williams' paper. He remained but a very short time on the ground, and devoted his attention exclusively to the discovery of coal

Mr. Williams.

and iron. As the present survey has been carried out in much more detail, it would only be a repetition of information to refer at length to Mr. Williams' report.

The Káranpúrá occupies, like the Bokáro coal-field, the low ground of the Damúdá valley at the base of the southern scarp of the Hazaríbágh table-land.

It is comprised between 84° 51′ and 85° 30′ east longitude, and 23° 37′ and 23° 57′ north latitude, and covers an area of 472 square miles.

Among the coal-fields of the Damúdá valley, it is inferior in size only to the Rániganj field; but though larger than either the Bokáro or the Jherríá, it is not so important economically. The total number of coal seams decreases in going from east to west.

The extreme length of the Káranpúrá field is forty-two miles, and its extreme breadth is nineteen. Its outline conforms with considerable fidelity to the course of the scarp of the Hazáribágh table-land, which overlooks it on the north, and to the other metamorphic hills which limit it on the east, west, and south.

Denudation has, of course, in many places done much to modify this agreement of outline with the contour of its natural boundaries; but, roughly speaking, the coal measures are still found in all the larger sweeps and indentations which the ranges present.

Physical appearance.

The chief features in the physical appearance of the field resemble those of the Bokáro area. Talchír, Damúdá and Panchét rocks occur, and each series exhibits that surface contour which is characteristic of it.

Flat stretches of Talchírs contrast with the hillocks and low scarped table-lands of the Barákars; and wide level expanses of ironstone shales, Rániganj and Lower Panchét rocks, throw into bold relief the massive hill lands of the upper Panchéts.

Maudíh hill.

The most prominent hill of this latter series is Maudíh, which covers an area of 45 square miles, and is, therefore, much larger than Lúgú hill in the Bokáro field. Its appearance, however, is not so bold and striking, owing to its smaller elevation above the level of the plain out of which it rises. Nevertheless, viewed from the high level country in the vicinity of Lúrúngá, it looks imposing; the massive sandstones forming its eastern and northern faces, rise sharp and precipitous from the plains, and retain this character as far as the eye can trace them, whilst an ill-defined idea of the magnitude of the hill creeps into the mind from the extent of view opened out.

The southern aspect is not so commanding as the northern; the cliffs do not rise as high, and they are not as precipitous. A few streams break through and over them. The largest and finest of these falls down the face of the hill is near Butka, forming a series of deep rocky pools joined by tiny cascades. The scenery along its banks is very pretty, and a climb up its rocky bed affords a pleasure to a lover of natural beauty which more than compensates for the bodily labour entailed. The top of Maudíh hill is more or less a table-land, the sandstones of which it is composed having only a very slight synclinal curvature. This feature has been favourable for the accumulation of soil, in many places of considerable depth.*

Satpahrí hill.

Separated only by the valley of the Chúndrú or Tendwá river, the Satpahrí hill occurs west of Maudíh. Its area is 12 square miles. The Danhú and Harhí hills belong to the same series as the larger hills, and they present much the same appearance, differing only in respect to size.

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* European enterprise has utilised some of these spots for the cultivation of tea; and when I first visited the hill in 1865, I found 50 acres of ground planted out.

Gerwa hill is the only one of any dimension that does not lie in

Gerwa hill.

he strike of the others. It is adjacent to the southern boundary in the west corner of the field. In discussing the relations of the different rock groups, I shall refer again to this hill.

Beyond the field, the most important and conspicuous of the

Hazáribágh and Chotá-Nágpúr table-lands.

elevated areas, are the Hazáribágh and Chotá-Nágpúr table-lands, which form, respectively, the northern and southern natural physical boundaries of the coal-measure series. Their general height above the sea is 1,900 to 2,000 feet above the sea.

As the Hazáribágh table-land extends westward, the difference between its average level and that of the low lying ground of the valley, decreases; and a perceptible narrowing in its breadth is observable about the meridian of Hessátú.*

Accompanying this circumstance of narrowing, it is noticeable that the coal-measures facing the northern scarp of the table-land, approach nearer to those at the foot of the southern scarp; and I think it probable that they once closed round the extremity of the table-land in the vicinity of Katkamsándí.†

The Chotá-Nágpúr table-land extends in a well-defined and uninterrupted manner much further to the west than the valley of the Damúdá. It forms the natural physical boundary of the south Káranpúrá, as well as of the Káranpúrá, field, and it may roughly be assumed to be the limit of the coal-measures in the valley of the U'rangá.

The western range that borders the Káranpúrá area is not continuous. It consists of separate hills, some of which rise high above

* A village twenty-five miles distant from Hazáribágh, and in a direct west line.

† This village is not included within the limit of the map accompanying this memoir.

the plain. They are for the greater part made up of metamorphic strata, but some are capped by unaltered sandstones and shales, and by laterite.

These rocks invariably betray their presence by the flat appearance of the hill upon which they occur, and the contrast between these and the picturesque ragged-peaked, and sharp-ridged metamorphic hills is strikingly seen in the same range.

Drainage.

Owing to the situation of the field, so near to the head of the Damúdá valley, most of its drainage channels take their rise, either within the area of the sedimentary rocks, or at a short distance beyond their boundaries.

Damúdá.

The only river of any dimension is the Damúdá. It enters the field near Mahlan, but it is no longer the broad open river which passes by Ráníganj, but a small stream scarce 50 yards in width. Its channel increases in size as it goes eastward, and when it leaves the south Káranpúrá field opposite Changarha it is of considerable breadth.

Nowhere does the Damúdá present any special beauty of scenery, and the same remark holds good whenever it passes through the sedimentary rocks of the other coal-fields.

When gneissose and other metamorphic strata form its bed, it exhibits some diversity of appearance; but, as a whole, the Damúdá is a river devoid of any scenic attractions. Throughout its course, as far as I have traced it, from Ráníganj to near the base of the Chotá-Nágpúr table-land, I know of only one locality that deserves mention, and that is, where the Béra nadí meets the Damúdá, near the eastern boundary of the Rámgarh coal-field. Here, the combination of rock, wood-land, and water scenery, is well worthy of admiration, and my colleague, Mr. Ball, has graphically described the beauty of the spot.

The chief water-sheds are the Chotá-Nágpúr table-land, the Hazáribágh table-land, and the hills of Panchét rocks in the middle of the field. All the northern tributaries of the Damúdá are thrown off by the two latter water-sheds, and they contribute the greatest body of water. The river Damúdá* rises in the Chotá-Nágpúr table-land.

The western range of hills that borders the Káranpúrá area, and in which the gradual ascent of the plains of the Damúdá valley culminates, is important as forming the water-shed between some of the tributaries of the Koel and those of the Damúdá river.

From the configuration of the country surrounding the Káranpúrá field, a student of physical geography would at once surmise that the number of streams traversing the coal-measures was very great. This is the case, and there is no field in the whole of the Damúdá valley that contains so many rain channels as the Káranpúrá. A rough estimate gives, for an area of 500 square miles, a river drainage of more than 2,000 miles in length. All the streams are extremely shallow, and soon after the cessation of the rains contain only a small quantity of water, which usually dries up in the early part of the year. After a rain-fall, a considerable volume of water is conveyed to the Damúdá, sufficient indeed to render the river navigable for short periods. As a highway of communication, however, it is useless.

Tributaries of Damúdá.

The most important tributaries of the Damúdá on the north or left bank, are the Hohárú, the Chúndrú or Tendwá, and the Múrpá river. Nearly the whole of the eastern part of the field is drained by the Hohárú and its feeders.

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* The river Damúdá takes its origin in the country of the Múndás, and its name has by some been considered to signify "the waters of the Múndá," *dah*, in the Múndá language, meaning water. Damúdá may, however, be translated "waters of the snake," *damun*, being the term employed for a water snake. The most important caste amongst the Múndás is the Nágbansí, and as *Nág* implies a snake, there may be some connection between *damun dah* (Damúdá) and *Nágbansí*.

It possesses several local names, being called, in addition to Hohárú, the Palándú, Barká, and Galgaliá nadí. The largest affluent of the Damúdá in the western part of the field is the Chúndrú. It exposes an excellent section of the various rocks, and affords several striking examples of the cutting power of water. From the south the two largest streams that flow into the Damúdá, are the Saphí and the Chattí; both of these rise in the Chotá-Nágpúr table-land.

The whole of the Káranpúrá area is well covered by jungle, and according to the nature of the soil this differs in character. The more common trees are those which are ordinarily found throughout the whole of the jungle in Bírbhúm,* Mánbhúm, and Hazáribágh. There are few large trees at present; the demand for charcoal to supply the wants of the numerous iron-furnaces and refineries leading to a great destruction of timber. The only locality where wasteful cutting is not allowed is on Maudíh hill; and the timber is yearly improving; the yield, however, will never be great enough to form a permanent supply for any great smelting works, or for any considerable demand in the way of sleepers.

Inhabitants.

The inhabitants of this district do not give promise of a good mining population. The greater number of people belong to castes that cannot be called low. Numerically, the Kúrmís hold the first place, then come Koirís, Gwalas, Khairwás, Bahmans, Brahmans, Rájpúts, Káhárs, Múndás, Mussulmáns, Télís, Dhánúks, Ganjús, Bédíahs, Saontárs, &c. Of all the castes enumerated above, only the Múndas, Télís, Bédíahs, Ganjús, and Saontárs, will supply workmen for underground operations, and unfortunately these castes are weak in numbers. There are only three villages of Saontárs in the Káranpúrá field; and these are remarkable as being the most advanced westerly settlements of this interesting people.

* A paper read by Mr. Ball before the Asiatic Society of Bengal, at their November Meeting in 1868, on the flora of Mánbhúm applies equally to the Hazáribágh district.

Should miners, however, be required over and above the local supply, the district of Chotá-Nágpúr, with its Koles and Múndás, would always be a good recruiting ground.

Geological composition of Damúdá valley.

Before entering upon a special description of the rock formations of this field, it will be expedient to present a concise sketch of the geological composition of the Damúdá valley. Commencing near Rániganj, where the rocks are first seen to crop up from under the alluvium of Lower Bengal, we find that three distinct series of sedimentary beds occur, resting upon a floor of metamorphic strata. Each series is separable on the ground of at least apparent unconformity, and is more or less perfectly divisible on palæontological evidence. As we proceed further up the valley of the Damúdá, we find a repetition of the geological structure of the Rániganj area; no new series appears, and the stratigraphical relations are but slightly modified.

The lowest of these three series is the Talchír; overlying it, is the Damúdá, and above this is the Panchét. The Talchír is subordinate in thickness to either of the other series; but it is more constant in the character of its strata. Its characteristic rocks are fine-grained sandstones, silty shales, and conglomerate beds.

The Damúdá comprises argillaceous and silicious sandstones, shales, and numerous seams of coal. Its greatest development is in the Damúdá valley, where it is divisible into three distinct groups. Towards the west, the sub-divisions are not so marked, and, in the wide spread area of the Sirgújá and Central Provinces' coal-fields, only one group is recognisable.

The Panchét is a very extensive formation in the valley. The most prominent hills within the limits of the various basins, are made up of the rocks of this series. It has been divided into two groups; each differing very much in the character of its strata. The lower

consists principally of red and green clays, micaceous sandstones and felspathic sandstones, often calcareous. The upper group is almost exclusively composed of ferruginous sandstones, grits and conglomerates. In the Ráníganj field several forms of Labyrinthodont reptiles have been found in the lower group, which help to establish the age of these rocks. The extension of the Panchét series over other areas than the Damúdá valley is very great, and the definition of its limits is one of the most important tasks on which the survey is now engaged.

The three series which I have just described embrace the principal sedimentary deposits of the Damúdá, and they are found in each of the different coal-basins, with the exception of the Jherríá and the Rámgarh fields.

The Talchír Series.

It will be seen by consulting the map that the Talchírs occupy an area of only 9 square miles; cropping out irregularly along the edge of the field.

I need not recapitulate the peculiar characteristics of the Talchír strata, considering how fully they have been described in foregoing memoirs. The bottom bed is the boulder conglomerate: and above it, is the usual succession of fine-grained sandstones and shales with an occasionally interstratified boulder bed of small thickness.

Remnants of the series occur between the Bokáro and the Káranpúrá fields. The largest of these outliers lies north-east of Rikbá and due east of Khapíá. It is chiefly composed of fine shales, but at the bottom is a greyish green sandstone. This is mixed with fragments of quartz along its western boundary where a quartz breccia exists. This occurrence is apt to create an idea that there has perhaps been a fault, subsequent to the deposition of the sandstone. I could, however, perceive no signs of crushing, and it is more probable that the

Talchírs were deposited against and over the quartz-reef, and the fragments of quartz in the sandstone were debrís enclosed during the formation of that rock.

Boulders and pebbles washed out of the bottom conglomerate are found all over the gneiss intervening between the Káranpúrá and Bokáro fields: thus recording the intimate relation that exists between the two areas and pointing out the probable former continuity of the two areas.

The exposure of the series in the main body of the field is very small, a narrow strip occurs along the eastern boundary, slightly faulted on the north. Occasional outcrops are met with along the northern and southern boundary, but none on the western.

Everywhere the Talchírs are in natural contact with the gneiss except south of Rikbá, where a fault which cuts off the other series of rocks affects them likewise.

Fault.

This fault is one about which there can be little doubt, as there is mechanical evidence in the form of a "slikenside" to support the first impression of the existence of a throw which would naturally be drawn from the disturbed lie of the beds, and the consecutive appearance of the different series at the boundary.

The best spot for studying the mechanical evidence is about two miles west of Chano in the stream which flows from Passaríá, and past Jarjarrá in the south Káranpúrá field. The contact rocks show signs of scoring, and in places present a glazed appearance. None of the sections of the Talchírs expose more than 400 feet of strata. The most typical of all is the one in the Kassiátic river which flows south of Misrole in the north-west part of the field. The boulder bed, shales, and the sandstones are characteristically developed.

A look at the map will show that the areas of the other outcrops of Talchírs are very small, and as there is really nothing to say about

their mineral or stratigraphical features, I shall conclude this notice of the series by a few remarks on the organic remains which it has yielded.

Flora.

I merely mention the word 'fauna' to draw attention to the absence of any evidence of animal life more distinct than annelid tracks. The search for plant remains, however, was more successful. In the higher beds of the series, below the junction of the Tordág and Lúrúngá streams, some well preserved fronds of a *Glossopteris* and *Cyclopteris* were found. They occurred in an extremely fine grained, greenish grey sandstone, about 30 to 40 feet, below the base of the Barákar group.

In this instance as in every other throughout the Damúdá coal-fields, when fossils are met with in the Talchírs, it is always near the top of the series, when those physical conditions appear to have been approaching, which were afterwards to sustain the wonderful vegetable energy of the Damúdá period.

The Damúdá Series.

This series which is emphatically the true coal-bearing series of India exposes an area of 371 square miles. It is divisible as usual into its three groups,—an upper and a lower set of coal-measures separated by a series of ironstone shales,—Barákar, Ironstone shales, and RánígaNj.

They do not present quite the same lithological aspect here as in the other coal-fields of the same valley. There is a gradual change in the texture of the sandstones and in the relative proportions of quartz and felspar, and there is an increase of lime in their composition as they extend westward. These distinctions have, of course, no special bearing on the physical conditions of formation of the sandstones, but such changes are worthy of note.

The ironstone shales diminish rapidly in thickness from east to west, and they do not, as far as present researches prove, occur to the west of the Káranpúrá area.

The unconformity of overlap exists as a ground for separating the groups; but in addition there is, from a purely economic point of view, a good reason for establishing a sub-division of the series. Coal is only found in the upper and lower groups: the ironstone shales being devoid of anything more advanced towards the condition of coal than carbonaceous shale.

In Bengal, the Damúdá series has not yielded any remnant of a fauna upon which to found data as to its age.

In the Central Provinces, however, an *Archegosaurus* was exhumed, and it will help to determine the place which this series occupies in the chronological history of the formation of the existing earth's crust.

Paucity of animal remains in the older formations.

The absence or paucity of a fauna is not peculiar to the Talchír and Damúdá series. Other formations are as badly, or nearly as badly, off. The Vindhyans, exceeding ten thousand feet in thickness, have yielded no well-authenticated animal remains. The lower Panchéts, which immediately overlie the Damúdás, have furnished only a small store, whilst the upper Panchéts, and their representatives in S. Rewah, the Central Provinces, and south of the Nerbudda valley, and, again, the 'Jabalpúr' beds, are almost without a fauna. Indeed, throughout India generally, leaving out of consideration the formations of the Himalayas and salt range, none of the older series of rocks are really fossiliferous.

It is impossible to assert what the cause of this extraordinary poverty was, but the fact of this poverty must be held to prove, that the conditions under which these different formations were deposited, were unfavorable, either to the development of animal life, or to the preservation of animal remains.

I shall refer to the flora of the Damúdá series further on when speaking of its age.

With the above general remarks, I shall now proceed to describe in full detail the lithological characters of each sub-division, commencing with the Barákar, and refer specially to their local distribution, and to the seams of coal that occur in them.

Barákar group.

This is the lowest group of the Damúdás, and everywhere, excepting in the Ráníganj district, is the one richest in workable beds of coal. There are three fairly marked divisions of the strata, but I have not attempted to trace them out minutely in the field, owing to the great amount of time and labor that would have been involved, without any practical result, as regards the economic value of the group, which in the present stage of our geological researches is the most important object to keep in view. The lowest division of the Barákars consists of pebble beds, coarse sandstones and grits, and coal seams of large size.

The middle division does not possess pebble beds. Its sandstones are finer grained, it has coal seams of moderate thickness, and there are several beds of iron ore.

The upper division is made up mainly of shales and shaly sandstones, with iron at the top, and coal seams of small size.

The physical impress of the lower Barákars is very decided. The coarse grits at the base, together with the pebble beds, produce a series of low hills of a rough uneven appearance, often in more or less parallel ranges with shallow ravines and vales between. The country which these rocks occupy is always sterile, and can only bear thin spreads of jungle.

The middle and upper Barákars produce a nearly level surface, and thus conform to the type of country which usually results from the degradation of the ironstone shales and the Ráníganj beds.

Distribution.—As regards the coal-field now under description, it has the structure of a comparatively shallow and somewhat oval basin, or broad synclinal trough, with a general inward dip of the strata from all parts of the periphery towards the centre; but it is not exempt from local undulations.

Chano basin.

The extreme eastern part of the field is almost a little basin apart from the rest; the coal-measures around Chano and Rikbá being nearly cut off by an area of gneiss from the main body of rocks. The Barákars are well developed here. They rest naturally along their boundaries (on the crystallines) where they overlap the Talchírs, except in the case of the southern border. The bottom pebble beds and grits form a cliff of some size west of Hosí, and the sandstones east and south of Khapíá are massed together in slightly sloping table-lands. I did not meet with much coal in the Barákars in this little basin; for with the exception of a few outcrops in the Kowa river I failed to note any seams. The largest bed of coal is two feet thick where it shows in the bank of the stream. The dip is westerly and very slight in amount.

I cannot speak of the quality of the coal or of the value of the seam with any degree of authority. Its thickness appeared to me to be too small to allow it a rank amongst the useful beds of fuel. Even for local requirements I should be inclined to recommend the coals of the Ráníganj group in preference.

Going down the Kowa river from this two-feet-seam to the junction of the Chano stream, no coal bed of the slightest importance is visible, and with the exception of one thin carbonaceous band to the east of Rikbá, there are no outcrops exposed of anything resembling coal in this little basin, but those which I have referred to.

Communication difficult.

Communication with this portion of the field is difficult, as it is surrounded by hills on almost every side. In the direction of Lúrúngá and Chano on the west, Rikbá on the south, and Kosí and Khapíá in the north and north-east,

the ghats are impassable even by the ordinary carts of the country. The only outlet is towards the south-east end of the field. Any demand, however, in that direction would be more readily met by drawing upon the resources of the Bokáro and south Káranpúrá coal-fields. We therefore see, that this Chano basin is not adapted to contribute towards meeting the requirements that may possibly in the future be made upon the coal supplies of the Káranpúrá field.

Passing from Chano westward, there is an ascent to the high land upon which Lúrúngá stands: and thence, there is a descent into the main plain of the coal-measures.

Coal at Lúrúngá.

There are two seams to the east of Lúrúngá, one of which is very thick, and contains good coal. Its dip is low, and it can be easily worked, but its position is not good, being difficult of access owing to the hilly nature of the ground and the absence of roads.

Near Indra, a village two miles south of Lúrúngá, there is one seam. At its outcrop it has not the appearance of being of any value, and its situation, as in the case of the preceding coal beds, is equally unsuitable for mining operations.

There is a difference in the levels of the Barákar rocks in the Chano basin and those around Lúrúngá and Indra. Mr. Williams, who also noted this fact, ascribed it to a north and south fault, along the edge of the inlier of gneiss and having a downthrow to the east. There is no evidence, however, in my opinion, to support this view; and a simple flexure of the strata steeper on the one slope than the other would account for the difference of level.

The Barákar sandstones to the west of Lúrúngá are felspathic and friable, and of a greyish white color. They sweep round steadily to the southern boundary, and form a strongly marked horizon in the group, and a prominent physical feature of the country. As they extend towards Passariá, they become altered to a great extent at the surface by the

infiltration of iron. This metamorphism takes place to a depth of two and three inches. It gives them the appearance of beds of the upper Panchét series; and my first impression on seeing them was, that they belonged to that formation. By breaking away the upper crust, however, their true character is exposed.

West of Passariá, they form a glacis which is three to four miles long, sloping gently from the village towards the river Hohárú. In many places in this glacis, the rocks have been weathered in the most peculiar manner, and the natives give them the name of "tiger's paw stones." Small pinnacles and domes are left here and there, and their whole surface presents the appearance of successive irregular circles of little scallop-shaped recesses, the floors of many of which bear a rough resemblance to the impress of tiger's feet.*

Although this weathering is more particularly apparent in those portions of sandstones which stand up prominently in the shape of domes and pinnacles, the entire surface of some parts of the glacis for several hundred square feet are eaten out in the same fantastic manner. At Sore-bassi-kargá† (north of which this peculiar weathering is hardly met with) this is the case, and the effect on the eye from a distance is like that of a lake surface disturbed by a gentle blowing of the wind.

The thickness of the Barákars in this part of the field is not at all constant. A cross section from Lúrúngá to the village of Náppo exposes no other rocks than sandstones and ordinary shales up to the

* This is peculiarly well seen in a small dome to the left of one of the roads leading from Koilan to Passariá. In addition, however, to the impressions of tiger's feet, there are some which resemble those of bullock's feet. This circumstance has given rise to a legend of an extraordinary fight which once took place between a tiger and a bull. The latter being hard pressed took refuge on the dome, and standing at bay succeeded in repelling all the attacks of the tiger. They alternately charged each other during a whole day, and their perseverance won for them a lasting fame, by allowing their feet time to wear the rock and leave their impress upon it.

† Portion of jungle south-east of Dokátánd.

boundary of the true Ironstone-shales group. By going south, however, from Náppo, a series of ferriferous shales are met with, many of which have the concretionary structure of the Ironstone group. The discovery of these beds added doubt to those which first assailed me, as to the propriety of placing the tiger's-paw sandstones amongst the Barákars; for, my first notion on observing the ferriferous shales was that they belonged to the true Ironstones; and I do not think this idea would have been dispelled, had I not fortunately been able to trace the tiger's-paw sandstones, into connection with the strike of the upper beds of the sandstones of Lúrúngá hill, and thus prove that the ferriferous shales were an intercalated band.

Accepting these shales as a datum line, from which to calculate the thickness of the Barákar group, it will be found that a much greater accumulation of strata exists south of Náppo, than along the line of section from Lúrúngá to that village. The tiger's-paw sandstones increase in depth as they extend southward in the direction of Patrá, and the grits and sandstones below the ferriferous shales maintain the same horizon which they exhibit in the Lúrúngá hill; so that leaving out of consideration the ferriferous shales, there is an augmentation in the thickness of the group. This fact points to a certain amount of unconformity in the Barákars, and the existence of great banks of sand during the period of deposition. And the intercalation of the ferriferous shales proves the synchronous accumulation of material charged with ferruginous matter, and of that which composes the ordinary sandstones and shales of the group.

It is very possible that the range of metamorphic hills north of Ango was a limiting shore of deposition towards which the currents set, and then being deflected there, the material that they carried was thrown down, forming a disproportionate accumulation of rock debrís.

The tiger's-paw sandstones do not occur in any part of the field other than between Náppo and Patrá. They form in this locality the

highest portion of the group; elsewhere, the sandstones and shales immediately underlying the Ironstone shales are of the usual felspathic and silicious variety which is characteristic of the Barákars.

The intercalated ferriferous shales can be traced from Passariá to Dokátánd, and no further. They are local in their development.

There are no outcrops of coal to be seen in the part of the field which I have just been describing, indicated by the villages of Passariá, Koilan, Dokátánd, nor Náppo; but there is no doubt in my own mind that coal does exist; and that if search were made for it by boring, we should find it at its usual horizon. The dips near Náppo and the other villages are low, and very favorable for the working of the coal.

Badmáhí river.

The *Badmáhí* river which flows past Gondalpárá and Badam, exposes a very clean section of the rocks, nearly opposite the former village. The measurements which I made are as follows:—

Ascending.

1.	A few sandstones and imperfect outcrop of coal.		
2.	Carbo-arenaceous sandstones	7′	9″
3.	*Coal* seam. The whole of this is not of good quality. The best portion occurs about three feet from the top	14′	4″
4.	Carbo-silicious sandstone containing impressions of stems		5″
5.	Slaty carbonaceous shale		6″
6.	*Coal*		3″
7.	Slaty carbonaceous shale		3″
8.	Coaly shale		9″
	Dip 10°.		
9.	Variegated black and white sandstone	1′	0″
10.	Red ferruginous sandstone		8″
11.	White silicio-felspathic sandstone passing into ...	2′	0″
12.	Variegated ribbon sandstone which passes into carbonaceous sandstone	13′	8″
13.	Coaly shale		4″
14.	Argillo-micaceous shales thinly laminated containing *ferruginous bands*	10′	0″

These bands are used for extracting iron from, but they are not rich. In this bed a very noticeable change in mineral character occurs along the strike, the ferruginous bands disappearing, and slightly carbonaceous ones taking their place.

15.	Felspathic silicious yellow, and much weathered sandstones. Four feet seen, the rest hidden.		
16.	Section obscured for 200 yards. Calculated ...	102′	0″
17.	Coaly shale. The lowest part not visible. It has been on fire, and forms a part of the spur running out in the direction of Gondalpárá. Thickness seen	4′	0″
18.	White silicio-felspathic sandstone	5′	4″
19.	Concretionary argillo-micaceous shales	11′	8″
20.	Red ferruginous band		8″

A well marked system of jointing heading south-west by south is seen in all these beds from No. 16 to the end of the section.

21.	Carbonaceous and *coaly* shale	4′	8″
22.	Ribbon sandstone, black and white	1′	8″
23.	More compact silicious sandstone		6″
24.	Silicio-carbonaceous shale	2′	0″
25.	Very fine grained purplish micaceous sandstone ...	6′	2″
	Dip 15°.		
26.	Silicio-felspathic sandstone with a band of carbonaceous shale three inches thick in middle ...	1′	9″
27.	Coarse sandstone containing small pebbles, stained red externally, and covered by patches of sesquioxide of iron	25′	0″
28.	Conglomerate band		2″
29.	Arenaceous sandstone	2′	0″
30.	Carbonaceous shale	25′	10″
31.	*Coal* seam	18′	57″
	a. *Coal* ... ... 2′ 4″		
	b. Carbonaceous shale ... 6″		
	c. *Coal* ... ... 11′ 6″		
	d. Carbonaceous shale ... 3′ 0″		
	e. *Coal* ... ... 1′ 3″		
	Total of coal ... ——	15′	1″
32.	Slaty carbonaceous shale	2′	2″
33.	Sandstone varying in composition		......
	Dip 12°.		

Section covered for 130 yards below this spot.

34.	Carbonaceous and arenaceous shale alternating ...	9′	0″

A short distance of the section is again obscured, after which a few feet of sandstone are re-exposed; and then the river rushes through a small gorge of thickly-bedded sandstone, afterwards to flow tranquilly over a sandy channel in which no rocks are visible.

In the above section we have at least two seams capable of yielding coal. They are very accessible, dip at a favorable angle, and contain fuel of more than average quality. The comparative goodness of the two seams can easily be determined on the spot if occasion require. The one highest in the section contains a greater proportion of coal than the other; but both are sufficiently large to be profitably won. Whether these beds ought to be worked by open quarry, or from shafts, will depend upon the permanence of any operations undertaken to utilise their fuel.

In the tributary of the Badmáhí which falls into it opposite Gondalpárá, there is no well-exposed coal seam. One obscure outcrop only is to be seen.

West of the Badmáhí river for more than three miles, the ground is too much covered up, to obtain any actual knowledge of the structure of the rocks; but it may safely be assumed, judging by experience gained in other fields, that the coal seams seen at Gondalpárá sweep round by Khapíá and Kasíadih.

That the horizon of the coal is more or less constant throughout the whole of the field, is a point which I shall assume to be correct.

Instead, therefore, of indicating the line of outcrops which the seams would probably follow in obscured ground, I shall leave to the common sense of those who may be charged with explorations, the duty of fixing their own positions, giving them as a basis upon which to found their calculations, the strike and dip of the sandstones and shales generally throughout the field, and of the seams of coal wherever exposed. The readers of this memoir will thus be saved the trouble of wading through a large amount of unnecessary matter; and it will be enough now to

indicate in the order of their geographical position from east to west, the various outcrops of a carbonaceous character which are of any value, either for rough work, or for the finer operations of iron smelting. The special quality of each coal will be finally treated of in the Economic Summary.

Commencing at the north-east end of the field, there is a crushed seam in the Mathra Ghat. I do not consider this of any value. Its normal dip is to the south.

The *Sahar* river which flows past Chandol, does not expose any coal in its banks that is of any value. The position here would be a very favorable one for a seam, on account of the easily accessible ironstone that overlies the Barákar group.

In the *Charíá* river, west of Lakra, the section is obscure, and no coal is visible. The boundary of the field trends northward from this place, following the contour of the scarp. The strike of the beds is also changed, and the dip, instead of being southerly, becomes southwesterly.

The *Bakwá* stream flows through Dainí Ghat, which is the principal highway between the town of Hazáribágh and the Káranpúrá valley. Outlines of Barákars, underlain by Talchírs, occur on either side of the river, at the foot of the ghat.

Coal near Aráhárá.

No coal of any value is exposed near the boundary, but opposite the village of Aráhárá there is a seam of some value. It dips at an angle of 18° south-west; and has a thickness of 22 feet. This seam is well suited for supplying the wants of Hazáribágh, as it is conveniently situated with regard to the chief traffic outlet of this part of the district. Much of the coal is of very good quality, and will probably not yield more than 8 to 10 per cent. of ash. There is a slight fault in the seam, but it will not affect the working of the bed.

There appears to be no coal in the river west of Sindwárí, and the same remark applies to the streams about Ehíj and Nowádíh. In the

Khowa river also, there is no coal, but there is a bed of carbonaceous shale 3 feet in thickness. The dip is south.

About half a mile north-west of Urtah, there is a seam 12 feet thick, and dipping at 10° south. Throughout an area of 18 or 20 square miles, this is the only considerable bed of coal which crops out at the surface. In the Baliá Beltú river, with the exception of a few rocks at the base, there is no exposure of strata; and north of Pagár and Báriátú, there are only outcrops of two or three seams, far too impure in quality and small in thickness to deserve any notice.

No coal indeed, worth calling attention to, occurs until we come to the Chúndrú or Tendwá river. A seam is exposed at its junction with the feeder flowing from the north of Ghangrá. It dips to the south at this place, but this is not constant, and it changes its strike, as it stretches westward. The seam is met with in the Kishanpúr road ghat, and can be traced for some way up the Ghangrá river. Its thickness is 11 feet at its outcrop, but the coal-yielding portion of it is less.

In ascending order, the following is the section:—

1. *Coal* seam		11′ 0″
a. *Coal* mixed	5′ 0″	
b. Carbonaceous shale	3′ 0″	
c. Sandstone	2′ 0″	
d. Coaly shale	1′ 0″	
2. White felspathic sandstone.		

The coal indicated by *(a)* is sometimes reduced to 3 and 2 feet. There is, however, a sufficient thickness of coal throughout the whole of this seam to supply any local demands.

Further down the river there are no outcrops distinctly visible.

In the *Pachandá* river, which is another tributary of the Chúndrú or Tendwá, there is a seam exposed just under the village. The thickness is not shown nor is the dip. The direction of inclination in the rocks near this, however, is south-east at an easy angle.

Coal near Pachandá.

Before proceeding further with my description of the coal seams, I wish to refer to some quartz reefs, which occur south-east of Sanbá. The question of most interest with regard to them is that of their age relative to the coal-measures. The test seems to me to be the contact phenomena. If there be crushing or brecciation along the lines of contact, then I should assume that the quartz reefs were younger than the coal-measures. Where I made my examination, however, I saw nothing which convinced me that they were younger; the Barákars seem to have been quietly deposited against them. These reefs run into the crystalline rocks, and one of them, as may be seen by the map, extends some way. In the *Honhí* and *Nowádíh* streams, which fall into the Amahár north of Saradho, there are two seams about half a mile above the confluence. The highest bed measures 6′ 8″, and dips at an angle of 8° in a direction slightly to the west of south. There is a slight fault in the seam running north-west south-east.

In the *Amahár* river there is a seam of coal a short way south of the ghat between Manátú and Barkotá. I cannot state what its thickness is, but it dips to the east. Somewhat higher in the series, east of the ghat, between Kúrlúngá and Súpáran, there is a small bed of coal measuring 1′, and dipping at an angle of 10° east. A few feet above is coaly shale 2 feet 3 inches thick.

From this point to the confluence of the Amahár and Chúndrú, nothing but sandstones and two beds of carbonaceous shale occur. I saw nothing resembling coal. The strike of the rocks in this river is not constant, but the changes are indicated on the map.

Coal near Pakarúá.

A seam of coal occurs close to the west boundary in the *Pakarúá* nadí, immediately south of the Banwar and Manátú road. It dips to the east at an angle of 25° to 30°, which decreases as the seam recedes from the boundary.

In the *Amákat* river there is a seam of coal which is exposed for more than half a mile when followed up in the direction of Arrah. Its

thickness is 5 feet, and it is capped by 3 feet of carbonaceous shale. It dips at as low an angle as 6° to the south-east, and south-south-east.

In the neighbourhood of Chamátú and Choura Jogipúrá there is no sign of coal, but in the *Ganespúr* river, just after its entrance into the field, there is a seam exposed measuring 77 feet in thickness and dipping at 15° to the south.

Coal near Ganespúr.

Above it, there is 26 feet of sandstone; and then a coal seam 3' thick.

The quality of the larger seam is not very good. But the middle portion will furnish a fair amount of coal. A fault running north-west and south-east causes a shift, the downthrow being to the north-east.

In the *Bisanpúr* river, which skirts the west end of Harhí hill, there are some large seams. The lowest in the series crops out about half a mile from the boundary. The following is the section in ascending order :—

1.	*Coal* seam		13'	9"
2.	Carbonaceous and fine grained sandstone		16'	0"
3.	Coarse felspathic sandstone		17'	0"
4.	Carbonaceous shale (blue)		3'	6"
5.	Fine grained bluish sandstone		30'	0"
6.	Concretionary carbonaceous shale		12'	0"
7.	*Coal* seam		21'	0"
	The bottom portion of this is the best, the upper part is merely shale.			
8.	Coarse felspathic sandstone		3'	0"
9.	Arenaceous shale		5'	0"
10.	Coaly shale		4'	0"
11.	Arenaceous shale		1'	0"
12.	*Coal* seam		5'	2"
	a. *Coal*	1' 2"		
	b. Coaly shale	2' 0"		
	c. Carbonaceous shale	1' 8"		
	d. *Coal*	4"		

The rocks obscure.

The dip of the beds mentioned in the above section is 18°, and it increases as we go down the river. There is plenty of good coal to be

obtained from the three seams, but the steepness of the dip is a great drawback. If only a limited supply of fuel, however, be required, it can be easily procured by surface workings.

In the *Pindarkone* stream, close to its confluence with the Bisanpúr river, there is a seam about 29 feet in thickness, including the top shale. Its angle of dip is 30°, and a part of it is let in by two faults trending north north-west. The eastern extension of the bed is met with in the Bisanpúr river.

I have now mentioned all the outcrops of coal which I met with in my examination of the north and north-western part of the field, and I shall now return to the east again, and describe the seams which occur in the southern division of the Barákars.

As before, I will refer to the coal beds in connection with the different rivers in which they are seen.

Coal in Damúdá.

Commencing with the *Damúdá,* the first outcrop is visible opposite the mouth of the Dúrgá sote, 8 feet 6 inches thick; and dipping northwards at an angle of 7°. The coal of this seam is of fair quality, and the amount of shale in it is small.

Nearly in the same horizon is another bed measuring 3′ 9″, and having a dip of 9°. It occurs at the bend of the Damúdá west of the Hapwá tributary.

These two seams are conveniently placed in proximity to the iron ores which occur near Hesahar, where there now are numerous native iron reducing furnaces. And the angle of dip is low enough to enable the seams to be easily worked.

Coal near Jámdíh.

The next coal bed is at least nine miles up the Damúdá, measuring by river distance. It is seen in the right bank and opposite the village of Jámdíh. The dip is north north-east.

Higher in the group comes a bed, facing the second river west of Hejdá. It is poor in quality.

The next seam is one measuring 7′, which crops out in the left bank of the Damúdá, at the bend south-east of Bhagiá.

Then come four seams a short distance west of the confluence of the *Chatí* river. They all dip to the east at an angle of 12°. The best of them measures 8′, and until it was worked out, the others would not attract attention. The remainder of the section of the Damúdá contains no outcrops of beds which are of any value.

Chúndrú or Tendwá river.—A small seam occurs about quarter of a mile above the union of the Chúndrú and Billárí rivers. This is not of much value.

Bétí river.—There is one seam in this river dipping at 5° to the north-west. Only the upper portion is valuable. The dip of the rocks south of this is very small, and in the Damúdá, the whole of the strata are inclined at a very low angle.

Hejdá and Khútkí rivers.—Coal occurs in the fields between Hejdá and Khútkí, and it is exposed in the river between the two villages for more than half a mile. At its outcrop it does not look very promising; but, in the absence of coal of any better quality in the vicinity, I would recommend its being used for local purposes. Its thickness is 5′ 6″, and its dip very low. This seam has the advantage of being accessible, and of being easily worked.

Túrhad river.—In this river there is a seam a little above its junction with the Damúdá; and there is another further up the river about a mile from the village. This latter seam dips at 5° to west north-west. I could not estimate its total thickness, but, of what I saw, the upper and lower portions were the best.

Hokárú river.—The only seams that are exposed throughout the entire length of this river are those at the mouth of the first and second

rivers respectively, west of Koilera. They measure 3′ and 8′ and dip to the north north-east.

*Ulatú river.**—One coal seam dipping north north-east occurs in this stream. It is at a distance of about three-fourths of a mile from the Hohárú.

Chatí river.—This river, one of the principal tributaries of the Damúdá, cuts through a few seams, but none that are of any great importance. The one lowest in the series occurs at the junction of the coal-measures and metamorphics. Its dip is 37°. It is of little value.

The other seams are exposed about three-fourths of a mile from the Damúdá, and the following is the section (descending) :—

1.	*Coal* seam		...	4′ 5″
	(a) Coal mixed	2′ 1″		
	(b) Grey arenaceous shale ...	8″		
	(c) Coal shale	1′ 8″		
2.	Sandstone		...	3′ 0″
3.	*Coal* seam (small).			

Seam No. 1 is seen in two places, an undulation of the strata repeating it.

Mahlan river.—Two seams occur near Kekrahí, dipping to east-south-east. They are neither of them of any importance.

Marmar river.—A seam exists west of the village of Marmar, dipping between west north-west and north-west. This is the only bed of coal worthy of mention in this neighbourhood.

Lúsingúa river.—A seam crops out in the Lúsingúa river, a few hundred yards west of its confluence with the Nagar stream. It is of comparatively little value.

* This river is not correctly mapped; and I would here remark that the delineation of the tributary drainage system of the Hohárú south of Satpáhrí hill by the *old* Survey is so thoroughly untrustworthy that I have not attempted to accommodate my geological lines to the rivers. I have taken as relative points the different villages; and the outcrops of coal which I have mapped will, with respect to them, be found to be pretty correctly indicated.

The foregoing paragraph terminates the enumeration of the known outcrops of coal in the Barákar group. A look at the map will show that there are large areas in which no seams are indicated. This fact does not imply the absence of coal throughout those areas, but merely the want of surface evidence which, in other parts of the field, is afforded by outcrops. I believe the coal to be nearly constant in its horizon; and therefore when we have made ourselves acquainted with one clear section, it will not be difficult for us to feel our way in searching for coal, even where there are no signs of it at the surface.

During my survey of the field, I was not able to collect very reliable data for estimating the thickness of the Barákars. There are several instances of the local exaggeration of particular rocks: one, such as the occurrence of the ferriferous shales east of Koilan, and another, the excessive development of the pebble beds at the base along the southern boundary. Near Loharsí on the Damúdá, they form cliffs exceeding 60 and 70 feet in height. Allowing then, for what may be termed irregularities, a fair average estimate would give the Barákars a thickness of between 1,500 and 1,600 feet. In the Rániganj field they are said to be 2,000 feet, whilst in the Jherríá they are more than 3,000 feet.

One of the changes in the mineral aspect of the sandstones of this group is the great accession of iron. In many instances, the bottom grits and sandstones are so altered in appearance that they resemble the rocks of the upper Panchéts, and considering the great weight that must necessarily be given to lithological evidence, where palæontology fails, it is difficult, in some cases, to determine correctly which series we are dealing with.

This accession of iron is a very fortunate circumstance. It has materially affected the industry of the district, and compensated largely for the non-adaptability of the group, as a whole, for agricultural purposes.

Ironstone shales.

This group constitutes the middle member of the Damúdá series, and, as its name implies, is distinguished by the occurrence of ironstones. In the Ráníganj field, where they were first noted, they are throughout almost of the same mineral character, consisting of very fine black carbonaceous shales, in which bands of concretionary argillaceous iron ore occur at intervals. In this field,—Káranpúrá—the shales are far less carbonaceous, and in many places they are purely silicio-argillaceous. The ironstone also does not yield such a large percentage of iron.

Distribution.

This group never covers a broad patch of land, but occupies a narrow band at the base of the Ráníganj group. They are best exposed east of Náppo, dipping 9° to the west.

Following up their extension in the direction of Badam, we find that west of the *Badmáhí* river, they become hidden by soil for some way. Indeed, they are rarely exposed afterwards. In the *Sakar* river close to Chandol, a section of them is to be seen. And again in the *Bakwá* and *Chúndrú*. These fixed points are a clue to the probable line of outcrop of the group in covered ground. In no other spots are they exposed, so that very much is left to conjecture in laying down their outline. The holings made by the Agariáhs (iron-smelters) in their search for ore, may be taken as a probable index of the proximity of the ironstone group, especially when such holings correspond, or nearly so, with the extensions of the lines of the fixed outcrops.

The group is overlapped by the Ráníganj rocks near Tendwá. On the south side of the field, it is nowhere to be seen to the south of the central hills of the Panchéts.

In the *Chúndrú*, the rocks are very well exposed. There are some concretionary bands, less ferruginous than the true ironstones, and in them I discovered plant remains, chiefly stems, with markings

somewhat like those of the genus *sigillaria*. Imperfectly preserved leaves of ferns are numerous.

The greatest thickness of the ironstones is about 600 feet, between Náppo and Usko, and then there is a gradual thinning out to the west.

In the *Chano* basin, there is a very good development of the group north of Rikbá. The drawbacks to the utilisation of the coal of this area which were enumerated before, apply equally to these ironstones.

As a source of supply we must look to the band which occurs in the main body of the field.

Ránígunj group.

The lower boundary of this group in the northern portion of the field partakes of the same uncertain character as the upper boundary of the ironstone shales. Very few contacts of the two groups are to be met with; as most of the rivers are shallow and sandy, and expose extremely imperfect sections. A very large area of the Ráníganj beds is obscured by alluvium, and thus the relations of the beds are often concealed in the most critical spots.

In the southern half of the field more rock is exposed, but the beds are not so distinctive of the group, as they are in other localities; and the complete absence of ironstones renders the fixing of the boundaries in many places a very arbitrary matter.

The texture of the Ráníganj sandstones is, generally speaking, fine; and like the normal upper Barákars, they contain none of those coarse sandstones and grits so distinctive of the lower Barákars; and as coal occurs in either group, there is no sharply marked character by which to be guided.

The distribution of the Ráníganj group is very simple: one small area in the Chano basin, and a larger, fringing the Panchét hills.

In the southern and western portion of the field the ironstones are entirely overlapped.

The amount of coal that occurs in this group is very small; and the localities in which I met outcrops can soon be enumerated.

Chano river.—In this stream there are four seams near Rikbá. The third in ascending order is 7 feet thick, and contains good coal. The dip is high throughout, the lowest inclination which I noticed being 37°.

Another outcrop is visible further up the river, which is possibly the continuation of one of the four beds near Rikbá.

The Ráníganj rocks overlap the ironstones in the neighbourhood of Chano.

In the main portion of the field, there is a seam 5′ 8″ thick, in the river south-west of Balliá. It crops out a short distance from the Hohárú. This seam does not appear to be of much value, but there is a certain amount of interest attaching to it, from the fact of its having been noticed by Mr. Williams.

Another seam is mentioned by that gentleman as cropping out near Paláudú, but I could not find it.

In the neighbourhood of Koilan, Patra, Paláudú and Kúnarú, there are some thin seams of coaly shale. I refer to them, because it does not always follow, that when the outcrop is small, the seam may not be thicker underneath, and consequently there is a chance of these beds being of workable dimensions.

Between the Dokátánd river above-mentioned as containing coal, and the Sahar nadí, the rocks are poorly exposed, and no coal occurs. Two very small outcrops are visible in the Sahar dipping south-west. The next coal is met with in the Chúndrú or Tendwá river. There are two seams dipping east-south-east at 15°. Near the village of Tendwá the dip is 45°, but decreases in the immediate neighbourhood of the houses.

The complete overlap of the ironstones takes place just west of the Chúndrú river.

Raham river.—I have applied this name to a little water-course west of the village. There are in it three very thin beds of coaly shale dipping south-south-east 10°.

Gondá river.—The plotting by the old survey of this river is so erroneous, that I cannot map properly the position of the seams which are exposed in its banks. But, at the top of the group, and near the ghat of the Gondá and Raham road, a thin bed of coal occurs. East of the ghat and close to a jungle road there is a seam 5′ 3″ thick,* dipping at an angle of 18° to east-south-east. The middle portion is of tolerable quality. A little lower in the series is another seam measuring 1′ 0″. The dip of this is somewhat more southerly than the other. Below this and still east of Gondá ghat there are two more beds, each a foot or so in thickness.

About two miles and a half west of the village of Gondá is an inlier of gneiss, against which coarse grained felspathic sandstones like Barákars are deposited. I have placed them amongst the Ráníganj group, notwithstanding their resemblance to the Barákars, for the reason that we may have identical strata repeated when the conditions under which they are formed are the same. I consider that the inlier of gneiss is, in relation to the sandstones which we see in contact with it, just the same as when those rocks were deposited. We have exposed by denudation the original shore against which the Ránígaпj sandstone was deposited. Had there been any evidence of faulting around this inlier, which might have altered its original relative position to the sandstones, I would have hesitated, without further proof, to place these sedimentary rocks in the Ráníganj group. On every side, the beds dip away from the inlier without exhibiting any excess of disturbance, and

* It would appear from my mapping as if this seam were unconformable to the overlying Panchéts. This arises from the relative positions of Rahaur and Sinda not being properly indicated by the survey.

we find also that the same sandstone is continuous around the gneiss. A fault on one side or other of the inlier would have brought different beds into contact with the gneiss.

Ganéspúr river.—The next coal, west of the last locality that I described, is in the Ganéspúr river, just at the mouth of the little tributary north of the village of Ganéspúr.

Going down the larger river, no more coal is seen until the beds are reversed, and then three or four outcrops are visible. The two highest beds in the series are small, but the third, which is about a hundred feet lower in the series than the second, is 2′ 6″ and of tolerable quality. Eighty feet lower than this is the fourth, measuring 1′ 3″ in thickness. The whole of the sandstones, accompanying those beds of coal or coaly shale, are thin-bedded and bluish in colour. The upper strata of the Rániganj are massive beds like those of the Dhardarwa nalá in the Bókáro field.

Chatí river.—The only other coal of which I know in this group occurs in the Chatí river, at the ghat between Hesálong and Gorialongar. It is about eight inches thick and dips to the south at an angle of 15°.

Respecting the flora of the Rániganj group I have to repeat the same story as of the Barákars. I failed to add any new species to our collection of fossil plants.

The Panchét Series.

During the examination of the Damúdá valley, the coal bearing rocks have always been the special object of attention, and the Panchéts have never been subjected to the same close scrutiny. Within the last year, however, the study of their relation to the rocks of the Sone and Central India areas has been the principal task of Mr. Medlicott, and that gentleman has satisfactorily shown that accepting the series as comprising both the upper and lower groups which are met with in the Rániganj field, it is found to stretch over an area of immense extent.

Locally the name of Pálí sandstones was given in the Sone or Réwá country, and that of the Kámthí rocks in the Nágpúr district. The identity of the Panchéts, as a series, with the Kámthís is, however, still a point not quite settled, although it is well known that the red clays and shales which are so characteristic of the former series, have been met with in great force along the Wardhá and Pranhitá rivers, associated with the sandstones and other beds of the Kámthís. As I know nothing of the Panchét series from personal inspection, beyond the limits of the Damúdá valley, I shall confine myself to this area. It was here that the age of this series was first determined; and it was here that its exact relation to the underlying coal bearing beds was first made out.

Stratigraphically there is little evidence to show unconformity between the Damúdás and Panchéts, excepting overlap. Wherever there are sections we find the two series conformable as to angle of dip. It is only when we trace them throughout the country, that we notice the disappearance of certain sets of beds.

In the mineral character of the typical rocks, there is a great contrast between the two series. The ferruginous element enters largely into the composition of the Panchét strata.

When we examine the palæontological evidence, we find that there is a considerable change in the fossil remains, such as plants; and that a reptilian fauna and a small entomostracous crustacean (*Estheria*) appear for the first time.

The sub-division of the series in the Ránígaṇj field was based upon petrological and mineralogical differences, but researches in the western fields have proved that the unconformity of overlap is again repeated. In the Latiahar basin the lower group almost entirely disappears, while the upper group becomes very largely developed.

The area covered by the Panchéts is larger in the Káranpúrá than in any other field of the Damúdá valley, being 90 square miles.

Lower Panchét group.—The distribution of the Lower Panchéts is very simple. They form a belt surrounding all the elevated lands of the upper group that rise from the middle and in the south-west corner of the field.

The characteristic beds are the red clays found towards the middle and in the upper part of the series. In the Káranpúrá district they do not form thick beds as in the Rániganj field, but resemble more those of the Bókáro in being thinly laminated, of slight thickness, and alternating with green micaceous clays.

The fine green highly micaceous sandstones, which are so noticeable in the Bókáro and Rániganj fields, are here represented by rocks of a much coarser type, and much less abundant in mica.

The finest sections of Lower Panchéts occur in the Girwa and Gondá rivers, and along the north face of Maudíh hill.

The mapping of the Gondá river on the maps we had to use is wrong, between Ráham and Gondá; and the boundary line of the Rániganj and Panchéts has been accommodated to the error. The true strike of the Panchét rocks near the village of Gondá is north-east, which becomes more easterly in the vicinity of Ráham.

Upper Panchét group.—The rocks of this group are very distinct from those of the Lower Panchéts. Coarse sandstones, grits and conglomerates are the characteristic beds. Shales are subordinate.

The boundary between the two groups is not always clearly marked, for sometimes in the Lower Panchéts there are ferruginous sandstones intercalated with red-clays, undistinguishable from the most characteristic Upper Panchét sandtsones. That there are good grounds for separation, becomes quite clear in some sections, for the conglomerates overlap the lower group entirely in places. One of the most notable instances is the south-east spur of Maudíh hill, between Ango and Bahká. The conglomerates are there seen resting directly upon Barákars. This is

one of the clearest cases of entire overlap in the field. I need not allude to other localities, specially where this circumstance of overlap receives confirmation. A look at the map will suffice to indicate where the same feature is repeated.

The thickness of this group is not great. Three or perhaps two hundred feet would probably be its maximum vertical development. The Lower Panchéts are far thicker.

FAULTS AND DYKES.

Faults.—The number of faults is less than I expected. One only is well defined—along the south boundary of the Chano basin. I have already alluded to the mechanical evidence of its existence. It ends abruptly, or seems to do so, near Bahká. In the Hoháru there is not very good proof of its presence, the only indication being a slight break in the sandstones along the line of its strike. The other faults are very insignificant, and require no special reference to be made to them.

Dykes.—There is an extraordinary absence of trappean intrusion amongst the rocks of the field, and the dykes which are seen are not traceable for any length. I met with only four exposures,—one near Baliá Beltú, another south of Nowa Khap, a third in the Gondá river, near its junction with the Chúndrú, and a fourth north of Sídpá. The effect of decomposition is seen on this dyke. The trap becomes a soft red rock with bundles of crystals tangled in it.

PART II.

The South Káranpúrá Field.

The original discoverer of this field was my colleague, Mr. Ball, in 1865, who gave it the title of the Túngí coal-field. He was not aware of its extent, having only partially examined it, and for the sake of reference adopted the name of the village of Túngí, which occupied a central position in the portion of the field which he mapped.

The village, however, is a collection of only five or six rude huts, inhabited by Bediahs, is not situated upon the coal-measures, and is scarcely known beyond a circle of three or four miles. I have therefore considered it more advisable to select a name widely recognised, which conveys an idea of its locality. Consequently, the designation of the parganáh has been adopted; and to show its relation to the larger coal field—the Káranpúrá—I have thought it better to call it the South Káranpúrá coal-field.

Its geographical position is comprised within the latitudes and longitudes given for the Káranpúrá. It occupies the low ground of the valley of the Damúdá extending along the banks of that river for a distance of nearly eighteen miles. To the south the field is overlooked by the scarp of the Ranchi or Chotá-Nágpúr table-land at a height of 2,000 feet above the sea. Whilst on the north, in its immediate vicinity, are the metamorphic hills of Ango and Garsúláh, and more remote the scarp of the Hazáribágh table-land.

The greatest length of the field is twenty-two miles, its average breadth four miles, and its area seventy-one and a half miles, of which three are occupied by the Túngí inlier of crystalline rocks.

Of the drainage there is little to say. The Damúdá is the principal river, but its only tributary of any importance is the Jainagar stream.

General Geology.—The same three series occur in this field as in the Káranpúrá, with the exception that no Lower Panchéts exist. It will be unnecessary for me to refer to the lithology of any of the series. Each is represented by beds similar to those of the larger field. I shall therefore confine myself almost exclusively to remarks upon the coal seams of the Barákar and Ráníganj groups.

TALCHÍR SERIES.

There is exposed of this series about half a square mile at the extreme east end of the field and a small strip near Rálígarhá. In the first of these a section is seen in a river not marked on the revenue map, but which is not more than a mile west of Hasla.

Purple shales and the conglomerate bed are the best developed. The sandstones are poorly represented.

Beyond the actual boundary marked on the map there are the pebbles and boulders of the conglomerate lying loose upon the gneiss: marking the former extension of this series. An interval indeed of not more than two miles separates the south Káranpúrá from the Rámgarh field.

DAMÚDÁ SERIES.

This series is represented by its three groups. The rocks are usually inclined at moderate angles, and the only high dips occur where faulting has taken place.

The unconformity of overlap between the different groups is as well illustrated as in the other fields. The ironstones are extremely well developed over a small tract, but die out rapidly to the west.

The total area of the Damúdás is 67 square miles.

Barákar group.—In this field this group seemingly contains much more coal than in the Káranpúrá. I suspect this is due to clearer natural sections being exposed than to the actual existence of a greater quantity of coal. And I feel inclined to accept the evidence afforded by

a study of the south Káranpúrá, as an index of the true thickness of the coal seams throughout the larger field.

Commencing as usual our description from the east, the first section is seen in the Sírká river.

Sírká river.—Proceeding up this river, from its junction with the Damúdá, no coal appears in the banks before we arrive nearly opposite the village of Ajgarhá. Two seams are there exposed. The lowest in the series, the thicker of the two, is 8 feet thick at its outcrop, and dips at an angle of 35° to north-north-west. The axis of a synclinal trending east and west passes a short distance north of the seam, and the beds previously observed are repeated, but dipping at a lesser angle.

For some way up the stream nothing but grits and sandstones occur, but from about the parallel of Túngí to the boundary of the field, *three* other beds of coal show. They are of small thickness and unimportant in consequence.

Marangarha river.—It appears from my notes that I did not observe any seams in this river. The section is very imperfectly seen owing to the sand. Iron-works are established on both banks, and some of the ore is obtained from the bed of the river in an iron-stone band, three-quarters of a mile north of the Agaríah village.

Near the entrance of the river into the field, a fault occurs inland on the left bank.

Damúdá river.—Although it would probably have been more in place to have noticed this river hereafter, it contains but a few outcrops of coal, and need only be somewhat briefly referred to.

Nothing more than a thin bed of coaly shale half a mile south by east of Dímwá, and a small bed of coal dipping 12° to south half a mile south by west from Polámundá, are met with before the place of junction of the Jarjarhá river and the Damúdá.

West of the Jarjarhá river some good coal occurs, dipping west-south-west at an angle of 11°. The section in ascending order is—

1.	*Coal* partially seen.			
2.	Carbonaceous shale		1' 9"	
3.	*Coal* seam		15' 0"	
	a.—*Coal*, middling quality ...	6' 6"		
	b.—Black carbonaceous shale ...	1' 0"		
	c.—*Coal*, good	1' 6"		
	d.—Sandy carbonaceous shale ...	3' 0"		
	e.—*Coal*, inferior	3' 0"		
4.	Beds obscure (about)		18' 0"	
5.	Coaly shale		5' 0"	
6.	Carbonaceous shale, concretionary		5' 0"	
7.	Coaly shale		3' 0"	
8.	Carbonaceous shale		2' 0"	
9.	Sandstone, a few feet			
10.	*Coal*, small thickness.			

These coal seams are cut off on the south by a large trap dyke, but their continuation is uninterrupted on the north and their outcrops are visible in the U'rímárí river.

West of the old Ránchí road, to where the Damúdá enters the field, I met with no outcrops of any coal. As the rocks, however, through which the river passes, are all Barákars, I think it more than probable that coal occurs.

Mohwátoláh rivers.—Returning to the east of the field there are two rivers near Mohwátoláh, one flowing east of it, and another west of it. The former exposes no coal, and the other* only one seam, possessing a northerly lie.

Jainagar river.—This is the river in which the principal seams of coal are seen. The section is unusually open, and affords a good opportunity for measurements.

* The rivers in this field are as badly plotted as those of the Káranpúrá. This one is wrongly shown as flowing into the Damúdá.

Commencing from the junction with the Damúdá, an obscure outcrop occurs half a mile north of the Sonda Changarha road.

At the road ghat there are two seams. The lowest is 2′ 0″ thick, and is separated by 9′ 0″ of sandstone; from the upper seam, measuring 5′ 0″, all the beds have a westerly incline.

The continuous section is, ascending—

1.	*Coal* seam (as above)		2′ 0″
2.	Sandstone „		9′ 0″
3.	*Coal* seam „		5′ 0″
4.	Sandstone „		65′ 0″
5.	*Coal* seam „		15′ 0″
	Dip 15°		
6.	Carbonaceous shale (imperfectly seen)		16′ 0″
7.	Sandstone		120′ 0″
8.	*Coal* imperfectly seen—about		3′ 0″
9.	Fine grained sandstone		2′ 6″
10.	Carbonaceous shale		1′ 0″
11.	*Coal*		10″
12.	Sandstone		3′ 0″
13.	Carbonaceous shale coaly		4′ 6″
14.	Coaly shale		3′ 0″
15.	Purple and carbonaceous shales		5′ 9″
16	Sandstone		1′ 0″
17.	*Coal* seam	10′ 2″	
	a. *Coal* of fair quality	3′ 6″	
	b. Parting	1′ 0″	
	c. *Coal* of fair quality	5′ 8″	
18.	Sandstone and grit.		

About 200 yards further up the river, there are two seams of coal measuring 12 and 14 feet, and separated by sandstone and shale 38 feet thick. The upper seam has 2′ 0″ of shale capping it. The coal in both seams is of fair quality.

A short distance up the stream, the junction of the Kúrsé river takes place.

From the mouth of Kúrsé river to the boundary of the ironstone shales, nothing but sandstones and shales are exposed. But south of

the fault, which is marked crossing the mouth of the small feeder at the bend of the Jainagar river, a great display of coal occurs. Unfortunately for economic purposes the dips of the beds are exceedingly high. I give the section in ascending order, commencing where the river enters the field :—

Boundary.

1.	Sandstone ...	173′	0″
2.	*Coal* seam...	2′	0″
	Small fault, north-west—south-east.		
3.	Fine micaceous sandstone	30′	4″
4.	*Coal* seam...	12′	9″
	Dip 60° north.		
5.	Sandstone ...	43′	0″
6.	*Coal* seam...	4′	4″
7.	Carbonaceous shale ...	6′	9″
8.	*Coal* seam...	12′	3″
9.	Sandstone, coarse	86′	6″
10.	*Coal* seam...	13′	2″
	Dip 48°.		
11.	Sandstone ...	16′	0″
12.	*Coal* seam ...	15′	6″
13.	Sandstone and shale ...	54′	7″
14.	*Coal* seam (upper portion good)	7′	4″
15.	Carbonaceous shale and sandstone alternating	29′	2″
16.	*Coal* seam stony	4′	4″
17.	Carbonaceous sandstone and shale	5′	0″
18.	*Coal* seam ...	11′	6″
19.	Sandstone ...	14′	6″
20.	*Coal* seam (good)	10′	3″
	Dip 40°.		
21.	Sandstone ...	103′	6″
22.	*Coal* seam ...	6′	6″
23.	Sandstone ...	13′	6″
24.	Carbonaceous shale ..	6′	6″
25.	*Coal* seam...	18′	4″
26.	Sandstone ...	72′	2″
27.	Coaly shale	7′	9″
28.	Sandstone ...	65′	6″
29.	*Coal* seam (with trap)	2′	3″

Dip 32°.

30.	Sandstone ...			13′	7″
31.	*Coal*			3′	0″
32.	Conglomerate bed			31′	8″
33.	Concretionary carbonaceous shale			21′	4″
34.	Obscure, but apparently *coal* ...			23′	9″
35.	Shaly sandstone			8′	4″
36.	Argillaceous sandstone			5′	4″
37.	Coaly shale ...			8′	4″
38.	*Coal* seam			13′	0″
	Coal (good)	2′	0″		
	Coaly shale	1′	6″		
	Coal (obscure) ...	9′	6″		
39.	Sandstone with carbonaceous and micaceous shales alternating			79′	0″

Dip 25°.

40.	Coarse sandstones and grits ...	296′	0″
41.	Sandstone ...	54′	9″
42.	Carbonaceous shales with incipient ferruginous concretions	16′	0″
43.	Sandstone ...	25′	0″

Dip 30°.

44.	Concretionary carbonaceous shales	85′	0″
45.	Sandstone ...	50′	0″

Fault west-north-west,—east-south-east.

The total thickness of the coal seams is 159′ 3″.

Many of them yield good fuel, and they are conveniently situated with regard to the ironstone shales.

The coal elsewhere in the field, is not exposed as abundantly as in the Jainagar river, and its existence must be actually determined by borings. Arguing from proved geological conditions, it is with very little hesitation I should assert the existence of coal over the greater portion of the Barákar area.

The remaining outcrops of coal met with by me were—

2 out-crops in the Kúrsé river.
1 out-crop in the Saiíland river.
1 out-crop in the Hendígír river.
3 out-crops in the Potangá river.

The section in the Potangá river is continuous and measurable. It occurs about 300 yards below the junction of the Potangá and U'rímárí rivers, ascending:—

1.	*Coal* seam, thin, dip 20°		
2.	Carbonaceous shale	6′	8″
3.	*Coal*	7′	3″
4.	Sandstone	18′	0″
5.	*Coal* (about)	10′	0′

All of No. 5 is not exposed. Further down the river it is again met with dipping at the low angle of 6° to south-south-east.

This coal is very accessible, and might be easily worked, and it occurs in the neighbourhood of some rich ironstone of the Barákars.

An Agariah village has been established about half a mile south of Potangá to work this ore.

Ironstone shales group.—This group is best developed in the Jainagar river, exhibiting its well known characteristics. Its northern and southern boundaries are not at all well seen; and between Túksúd and Tarpá, I am not quite sure that the out-crop, as I have marked it, is correct.

Near Pallo I saw a few carbonaceous shales and ironstones in a stream (not noted on the map), which I presume are of the ironstone group. As the section, however, is imperfect, it is very difficult to say, with any degree of accuracy, whether these carbonaceous shales and ironstones may not be a subordinate band of either the Ráníganj or Barákar groups. I have classed these beds with the ironstones, because they occur where the continuation of the undoubted ironstones would be found, if no intervening fault or faults displace them.

West of Pallo, the Ráníganj beds overlap, and entirely obscure the ironstones.

Ráníganj group.—The beds of this group are spread under Baiíá, Pallo, and Rúcháp, and to the south of Sákúl.

There is nothing to remark about them of any local interest.

With reference to coal, I saw only one out-crop, and that was in the second river west of Baiíá. It measured 3′ in thickness and dipped south-south-east.

PANCHÉT SERIES.

This series is represented only by its upper group on Patal and Henjdag hills, and occupies an area of 2 square miles. Of the Lower Panchéts there is not a trace. I searched carefully for any red clays and other characteristic beds, but failed to discover them. Their absence is not due to denudation, but to their never having been deposited on either the Patal or Henjdag hills. It is easy enough to climb up the face of each of these hills, and the section proves that there is conformity between the Panchéts and the rocks that underlie them.

Trap dykes.—There are two trap dykes of very considerable size, coming east-north-east, and damaging slightly the coal seams in the Damúdá.

Faults.—The only faults of any importance are one in the Jainagar river, and another south of Pallo. With regard to the former, there is a difference in direction of dip of the beds on each side of it; and there is an entire absence of the ironstone shales which ought to be exposed, if the normal section had not been disturbed. The other fault is made apparent by the sudden change in the nature of the rocks, on either side of a line drawn roughly north-north-east and south-south-west.

PART III.

General Considerations.

Having completed the purely lithological and stratigraphical description of the rocks of both fields, and having alluded to the physical features, the special topography, and the drainage of each, I shall now notice the several questions of geological interest which are deducible from the evidence collected during the examination of the valley, and finally give a summary of the resources of each field.

The facts which have been recorded in the foregoing paper, and the memoirs of the Geological Survey (treating of the Damúdá valley), relating to the composition, structure, and organic contents of the coal-measure rocks and the strata associated with them, enable us, with some degree of accuracy, to speculate upon the probable physical conditions under which these were deposited.

The most important consideration at the outset is the determination of the organic contents, for they teach us what the conditions of life were, and yield satisfactory data for the correlation of the different rock systems.

The great preponderance of fossil plants over other organic forms in the Talchír, Damúdá, and Panchét formations makes the name of the great 'plant-bearing series', as applied to these rocks, a very appropriate one; and in order to show that it is deserved, I append a synopsis of the principal fossil remains which have been discovered in the Damúdá valley.

Talchír series.—*Glossopteris, Cyclopteris,* a few stems, and some seeds. No distinct fauna.

Damúdá series.—

Barákar group: *Glossopteris, Vertebraria, Zeugophyllites,* trunks of trees. No distinct fauna.

Ironstone shales group.—*Glossopteris, Sigillaria (?)* and many indistinct forms. No evidence of a fauna.

Ránígunj group.—*Vertebraria, Phyllotheca, Pecopteris, Poacites, Glossopteris, Schizoneura, (?) Tæniopteris, Trizygia, Sphenopteris.* No fauna.

Panchét series.—

Lower Panchet: *Schizoneura, Tæniopteris, Sphenopteris, Neuropteris, Pecopteris, Preissleria.*

The fauna consists of *Labyrinthodont* and *Dicynodont* remains; the bones of some saurian distinct from *Dicynodon;* and an *Estheria.*

There is an entire absence of undoubtedly marine remains throughout these rocks. This fact impels us to favour most those views which advocate that the great plant-bearing series is a fresh-water or estuarine deposit. That the Damúdás and the Panchéts were formed under any other than fluvial, lacustrine, or estuarine conditions may be easily disproved; but with respect to the Talchírs, it once appeared to me very probable that the formation of the boulder bed at the base was due in great part to the agency of the sea.

In the report upon the Jherríá coal-field I appealed to the action of the sea upon a line of coast. I mentioned that the Island of Penang afforded an instance of a deposit now forming somewhat similar to the one that ushered in the Talchír epoch.

At that time, however, my observations upon the distribution of the boulder bed had been confined solely to the limits of each of the fields of the Damúdá valley. I was of opinion that it was only a fringing deposit; and if this had been the case, the hypothesis which I advanced would have answered every requirement,—a coast line of cliffs from which blocks of all sizes broke off, currents carrying along pebbles and drift, and a shallow sea.

It has, however, been shown that this bed is spread in some cases over many square miles, as, for instance, the area described by

Mr. Medlicott between the Sirgújá and the Sohagpúr coal-fields. A serious difficulty is thus opposed to the acceptance of the example which I brought forward; for the conditions existing there would only account for a fringing deposit.

The conjecture that was hazarded in the report on the Talchír field, that ground-ice might be the chief agent in the transport of boulders, receives no confirmation in the existence of scratchings on the stones, or angularity in the shape of the debrís. The absence of this testimony is, however, of no great moment, considering the mode of formation of ground-ice and the manner in which it transports material. The most serious difficulty, and the one which must be recognized, is that of climatal conditions.

Boulder beds occur high up in the series, and in the Bókáro coal-field, there is an instance in the Búdá (Boodah) river of a boulder bed in direct contact and conformable with a typical Barákar sandstone. Here, the contrast in climatal conditions is so forcibly brought before us that one ought to accept with caution the accuracy of the ground-ice-theory, until other explanations have been disproved which are *primá facie* more in accord with the conclusions deducible from the stratigraphical relations of the two series—Talchír and Damúdá—and the universally admitted conditions under which coal has been formed.

If we duly weigh the bearing which the evidence of unconformity that occurs between the Talchírs and Damúdá has upon the variation in climatal conditions existing during the deposition of the boulder bed, we find that the unconformity is one of mere overlap, and does not denote any great break in time of the process of deposition, such as is implied by the upheaval and denudation of one set of strata previous to the formation of another, but rather a change in the degree of intensity with which existing formative forces acted.

The relation between the Talchírs and Barákars is too intimate, as shown by the occurrence of similar plant remains and by the strati-

graphical conformity of the contact beds of either series, to permit us readily to admit the probability of a sudden alteration from the climatal conditions necessarily involved in any ice theory to those which have been considered essential for the growth of that vegetation to which coal owes its origin.

It seems more in consonance with the stratigraphical and palæontological evidence to allow that the three formations have been accumulated under almost similar conditions; and as there can be little doubt that the Damúdá and Panchét series are essentially fresh water deposits, the Talchírs may be classed in the same category.

Admitting then their fresh water origin, we have to determine whether they be fluviatile, lacustrine, or estuarine deposits. In the sandstones of the Damúdá and those of the Panchét series, we have evidences of current action resembling those which may be seen in the valley deposits of our Indian rivers.

The Talchír differs from the Damúdá and Panchét series, in that its strata are more uniformly fine grained, and seem to indicate more tranquil conditions of deposition. If we turn again, however, to our great river alluvial accumulations, we find that the features of the Talchír period are reproduced.

The extent and thickness of the needle shales are equalled by the recent deposits of our rivers; and with regard to the boulder bed, there are examples of it to be met with. One which I noticed was in the Wardha river coal-field, near Wargaon. The extent exposed was not much, but it was enough to see the possibility of such a deposit occurring in a river formation, in order to conceive its greater extension.

Limitation of deposition.—If we turn to a geological map of Lower Bengal, we find that the coal-fields of the upper Damúdáal, most without exception, occupy the low lying ground, limited by the elevated tablelands of Hazáribágh and Chotá-Nágpúr. The I'tkhúrí occupies the low ground fronting the northern scarp of the Hazáribágh plateau, and the

Jherríá, the Kárharbárí, the Déoghar, and the Ráníganj fields are all faced by high ground of metamorphic rocks at varying distances from their present boundaries. In the region of Palámaún, and in the valleys of Behar, where the lower series of the coal-measures occurs, there is this constant relation of high level metamorphics and low level coal rocks. Observing this relation, it remains to enquire whether it be due to sinking of the floor of the coal-measures within the limits of the metamorphic high ground, or whether the coal-measures were deposited approximately within their present boundaries. If the latter supposition be correct, it of course fixes the minimum age of the sculpturing of the Hazáribágh and Chotá-Nágpúr table-lands.

In the absence of proof of the existence of coal-measures on any of the high-lands, the tendency of the evidence that the rocks afforded within the limits mentioned above would have been to prove that, although the areas of the coal-fields have been modified by faulting and denudation, still their position relative to the high ground which limits them was due not so much to any throws, as to their original deposition in the low-lying ground which they occupy, but the occurrence of coal-measures on the Hazáribágh table-land, at a very much higher level than those of the Damúdá valley, sets the question at rest, by manifesting that considerable displacement of the coal rocks has taken place since their deposition.

This circumstance plunges us into the region of speculation regarding the original extension of the coal-measures, but, on the other hand, it affords us a clear light by which to interpret the nature of the boundaries.

Boundaries—faults.—The first consideration will be the relation of the different groups as bearing upon faults. In almost all these coal basins, the southern boundary is indicated as being a principal fault. This is based upon the fact that the rocks of the sedimentary series, which are found in contact with the metamorphic rocks encircling them,

generally belong to the highest formation developed in the field, from which it might be inferred at first sight that the whole of the underlying group of strata have been thrown to the extent of their known exposed thickness. This inference would probably be accepted without much question, if we did not interpret properly the indications of gradual overlap which the formations exhibit in each field.

In the reports of the Ráníganj, the Jherríá, the Bókáro, and the Káranpúrá areas, instances may be multiplied of the gradual thinning out of the different groups. The Damúdá series and the Lower Panchéts, as they extend westward from the Ráníganj district, exhibit a steady diminution in vertical development, which can be shown not to be due to denudation; for, in no case can the contact beds of any two series be said to be unconformable in the sense that implies upheaval and degradation of the lower rocks previously to the deposition of the newer. The unconformity, as has been insisted upon again and again in my memoirs on the Damúdá valley and by others also, is due '*to simple overlap* and to irregularity of deposition,' facts which are, to quote Mr. Medlicott's words, 'compatible with a close relationship among the groups as a series.'

If we push to its extreme length the conclusion that may be drawn from this evidence of gradual thinning, it would of course make all the southern boundaries of the Damúdá valley coal basins natural boundaries, not faults, and it would remove any speculation as to the nature of the original extension of the coal-measures; but unfortunately we cannot ascertain completely the rapidity of decrease, and several features of the rocks point to the operation of subsequent disturbing forces modifying the original boundary. We find also that on the north edge of the field, where the boundary is admittedly natural, the rocks exhibit less disturbance than on the south.

We naturally look to some cause for this contrast, and the one that most readily suggests itself is disturbance, such as always results in

faulting. The evidence of gradual thinning only tends to reduce the estimate which has been formed of the amount of throw of the southern faults, but it cannot be admitted as any positive testimony to the absence of faulting.

In the Káranpúrá field there is direct mechanical proof of the existence of the southern Chano fault, and thus we have one authentic example to confirm the conclusions which have been drawn from phenomena similar to those exhibited in the Chano basin; namely, greater amount or excess of disturbance along the boundary and the apparent depression of higher rocks.

Experience of every area, and more especially of coal areas, where the most careful observations have been made, proves the occurrence of faults of varying magnitude; and considering, that in these Damúdá valley fields the country has been subjected to similar crust-movements as those of other regions, I think it is but natural we should have similar phenomena exhibited.

By the admission of faults, the assumption that the existing orographical features of the country were marked out before the deposition of the coal-measures becomes untenable. For, we have to admit that the Talchírs and super-imposed series were most probably—when such a short distance only intervened as that which separates the measures of the Hazáribágh table-land and those of the Damúdá valley—deposited at the same level, and consequently the Hazáribágh table-land relatively to the Damúdá valley has undergone displacement to the extent necessary to bring about the present difference in elevation.

The general direction of the great lines of fracture is east and west, and as these occurred subsequently to the formation of the newest series associated with the coal-measures, we must assign a more recent age to the formation of the orographical features of the Hazáribágh and adjoining country than the Panchét period.

Talchír.—The Talchír flora is too imperfect to yield very satisfactory results, but the stratigraphical unity between the Damúdás and Talchírs tends to show that these two series are not widely separated in geological time.

Trap dykes and intrusions.—Observations upon the trappean intrusions of the Jherríá, the Bókáro, and the Káranpúrá areas, suggest no modification of the views expressed by Mr. Blanford in his report upon the Ráníganj field.

This trap is younger than either the Talchír, Damúdá or Lower Panchét period, but I know of no instance in the Western Damúdá fields of intrusions into the Upper Panchét group. A noticeable fact also is the decrease in the number of trap dykes from east to west. As regards the geological age of these intrusions, I can do no better than quote Mr. Blanford's words—'there appears good reason for supposing that these intrusions may have been contemporaneous with the great volcanic outbursts, of which evidence exists in the Rájmahál hills.'

'No evidence of later volcanic action is known to exist in any part of Bengal. The circumstance of scarcely any disturbance having taken place at a more recent period is in itself strongly in favor of the belief that the trap dykes of the Damúdá country are not newer than the lava flows of the Rájmahál hills, for had volcanic action taken place, it would probably have been either preceded or accompanied by disturbance. If, therefore, it be conceded that the age of the trap dykes is not newer than that of the Rájmahál rocks, the period during which they might have been formed is reduced to a comparatively small range.'

And the balance of probabilities appears to be in favor of those dykes being of Rájmahál age.

PART IV.

Economic Summary.

The detailed examination of these Káranpúrá fields has proved that they contain a very large supply of fuel, and are quite capable of meeting any requirements which are likely to be made upon them for industrial purposes.

With regard to their geographical position, they are conveniently situated between the towns of Hazáribágh and Ránchí, but the physical conformation of the country renders them difficult of access—in the ordinary acceptation of the word from either of those stations.

Occupying as the fields do the low level country of the Damúdá valley, and being hemmed in by table-lands and hills, it will require a considerable expenditure of money to open out a road for establishing communication between the valley and the up-land.

With reference to Hazáribágh, which is only fourteen miles distant from the nearest point of the Káranpúrá field, the easiest routes to open out are either of the two ghats, Mathra or Daíní. I would myself give the preference to the latter, because an extremely fine seam, the Árakara, occurs close to it; limestone (recent) may be obtained in its neighbourhood, iron ore exists in abundance, and its position with regard to the field is more central than that of any other ghat. This last fact is, I think, the strongest point in its favour, for the Mathra ghat taps the Gondalpúrá seams of coal and iron.

If any permanent way be opened up, the value of a position so central as that of Daíní ghat, with the collateral advantage of all the materials, requisite in constructive or metallurgical operations, being close at hand, cannot be overlooked.

In estimating the probable amount of coal contained in either basin, there is an element of uncertainty owing to the very few natural

sections which are exposed. I think, however, that in reviewing the evidence afforded by the Barákar group in the larger field, it has been quite proved that there is a thickness of between 30 and 40 feet of coaly matter at about 300 feet or so above the top of the Talchírs. This is the most important band of coal and the one which is the main stay of the field, and if we make it the basis of our calculation, we shall arrive at a very reliable minimum estimate regarding the capability of the coal-field.

The most constant subordinate band is about 10 feet thick, and occurs about 2 to 300 feet below the top of the group.

In the Rániganj series, there appears to be an available thickness of 6 feet.

If we take 35 feet of coal, making deductions for partings, and grant its extension over an area of only 250 square miles out of the 470, included by the field, we have 8,750,000,000 tons of coal.

In the south Káranpúrá basin, there appears from the evidence of the natural sections to be a greater abundance of coal than in the larger field. If we examine the two sections of the Jainagar river, we find, (*vide* p. 42) that there are eight seams, with a total thickness of 62 feet; whilst on p. 44 there are sixteen seams with a thickness of 159′ 3″. The discrepancy between the two sections is probably due rather to the broken nature of the exposure of the one as compared to the other than that there is such a rapid diminution in the thickness of the coal within such a short distance as that which separates them. I think it therefore safe to assume a thickness of 70 feet. Subtracting 20 feet for parting, and estimating this for an area of say only 15 square miles, we have 75,000,000 tons of coal.

These two valuations are very far below the actual amount that these fields contain, but even at the moderate computation which I have made, it is palpable that the Káranpúrá valley can meet the probable industrial requirements of Upper Bengal for years and years to come.

Regarding the excellence of the coal, the following assay may be taken as giving a fair measure of the quality of the better coals.

The specimen is from the larger of the Gondalpúrá seams:—

Carbon	64·5
Volatile matter	27·0
Ash	8·5

The amount of ash compares favorably with the ordinary Damúdá coals.

Iron ores—occur in abundance. Within the field there are two varieties—the clay iron ores of the ironstone shales and the hæmatite of the Barákar group. In the metamorphic area surrounding the field magnetic iron ore is met with in several places.

This variety of ores would be a great advantage to the iron manufacturer by enabling him to use judicious mixtures, so as to produce every description of iron acceptable in commerce.

The most abundant ore in the field is the clay ironstone of the middle group; and although no analysis of specimens from this field have been made, it has probably the same composition as similar ores from the Ráníganj area, where the average amount of iron is 35 per cent.

The richest ores come from the Barákar group, and yield from 50 to 60 per cent. of iron.

The following list gives the percentage of iron of several different varieties of iron ores collected by Mr. Donaldson and assayed for him at the Geological Survey Office by Mr. Tween:—

1.	Chepo Júgra	56·8
2.	Arahara (stream)	42·12
3.	Gondalpúrá (2 ft. seam)	37·3
4.	Mándú	33·8
5.	Belhargada	30·6
6.	Damúdá river (12ft. seam)	25·6
7.	Mairan Kalan	18·4
8.	Arahara	11·2

The magnetic iron ore must be looked for in the metamorphic rocks. It is the purest form of iron ore, and usually contains from 65 to 70 per cent. of metallic iron.

The manufacture of iron is one of the chief industrial features of the Hazáribágh district. Villages exclusively inhabited by Agariahs (or iron-smelters) are often to be met with, and the number of furnaces which are kept at work exceeds two hundred. The busiest season is the cold weather, as during the rains most of the men are engaged in cultivation.

Limestone.—This important material so essential as a flux, although found along the edge of the field in many places, does not, I am afraid, occur in sufficient quantity to be available for large works for a lengthened period.

Kunkur occurs over a large area of the field, but it is difficult to collect, and is of no great thickness. It is found along the banks of nearly every river.

The most important accumulations of fresh water limestone that I met with occur where the Beltú river falls over the face of the Hazáribágh scarp, and in the Daíní ghat.

Some crystalline limestone of very fair quality is exposed at the southern edge of the metamorphic inlier near Tungi (in the south Káranpúrá field) and also near Raí in the larger field.

Very silicious limestone, of little practical use, is met with on the table-land of Hazáribágh.

Date Due

MAR 4 '79	